The study of concrete ultrasonic rebound strength curve in Hengyang using ultrasonic-rebound conbined method

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ABSTRACT: Through the study of tests,the *'Technical Specification For Detecting Strength Of Concrete By Ultrasonic-rebound Combined Method' CECS02: 2005* of applicability situation in Hengyang was analysed to establish the ultrasonic rebound strength curve of this region,which was based on the least square method for fitting regression.Comparative study show that the regression equation which was established in the paper has better correlation and fewer errors than the unified national strength curve and was verified by practical engineering applicability in area of Hengyang.

INTRODUCTION

Entity engineering quality supervision is one of the important tasks of quality and safety supervision and concrete strength is the key indicator of entity engineering quality.With the unceasing development of detecting technology,a variety of detection methods are used to determine the concrete structure strength,and ultrasonic rebound synthetic method has been widely used in new housing structure concrete strength testing,which can reflects the elasticity and plasticity of concrete structure and internal structure and external state for comprehensively evaluate the quality of concrete in engineering field at present. According to the China engineering construction standard (hereinafter referred to as standard),the intensity of presumption is in accordance with the unified national strength curve,but it has a bigger error for the region,while area measurement curves is more accurate and more conform to reality than the unified strength curve.Owing to this fact,many areas have established a local curve which is more suitable for the characteristics of the region,and some relevant materials show that the experimental research has been carried out to establish the local strength curve which applies to the local and surrounding areas in Beijing, Shanghai , Nanjing, Shenzhen, Guangzhou, Tianjin, Wuhan, Hefei, Kunming and other places.In order to determine whether the unified strength curve is appropriate for evaluation of commodity concrete compressive strength in Hengyang area or not,108 blocks of ultrasonic

rebound tests and the ultimate compressive strength tests have been conducted.

EXPERIMENT PROGRAMME

Testing materials

Concrete specimen materials are from multiple commercial concrete mixing station of Hengyang region.The strength scope of designing concrete is C20-C50 MPa.

Main test apparatus

The main test apparatus are supersonic reflectoscope (a HC - U8 nonmetal ultrasonic detector produced by Beijing Hichance high-tech Co.,ltd),rebound tester (a ZC-3 type of rebound tester made by Leling rebound tester instrument production of factory in Shandong province) and the compression testing machine (a extra fine grade of TYE-2000B compression testing machine manufactured by Wuxi Jianyi company) . They conform to the latest requirements of the country relevant disciplines,have product certification and verification certificate,and are within the effective verification period.

Experiment

According to the standard requirements, the experimental study of local ultrasonic-rebound combined (local ultrasonic-rebound comprehensive) curve was carried out.Given that each strength grade was divided into 7d, 14d, 28d, 60d,90d and 180d (the ‘d’ means ‘day’) five corresponding ages,the concrete test specimens were made into 108 groups of 150 x 150 x 150 mm test cubes,with a total of 324 pieces.After concrete specimens of every strength grade finished molding in the same day,according to the requirements of specification, the test cubes were cured by standard curing method,and then get out of them,when meeting the stipulated maintenance age,to make the ultrasonic velocity (V_m) test which works at the front of cubes,rebound value(R_m) test which tests at the side of cubes,and compressive strength value(f_{cu}) test which have impact on the above and below of cubes after polishing.

The test results of the concrete rebound value and wave velocity in different compressive strength are shown in Figure 1 and Figure 2.

Table 1. Distribution of test data

Concrete type	Pumped concrete	
Varieties of coarse aggregate(1-4cm)	Cobble	Crushed stone (Limestone)
Sample quantities(n)	216	108
Stipulated age(d)	7-180	7-180
Curing method	Autotrophic after 7 days standard curing	Autotrophic after 7 days standard curing
Strength of concrete(MPa)	C20-C50	C20-C50

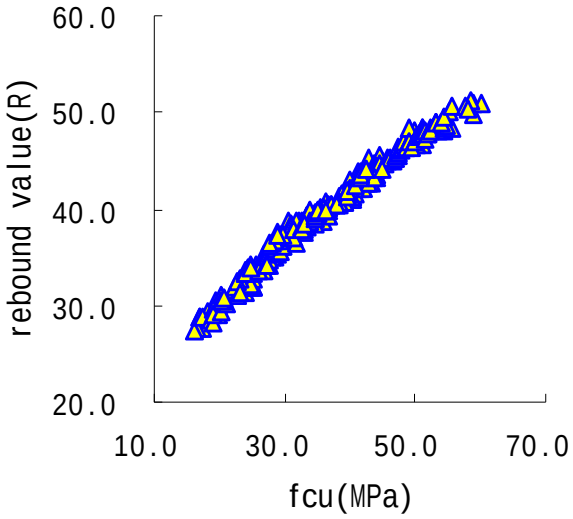

Figure 1. Correlations of the rebound value and the compressive strength.

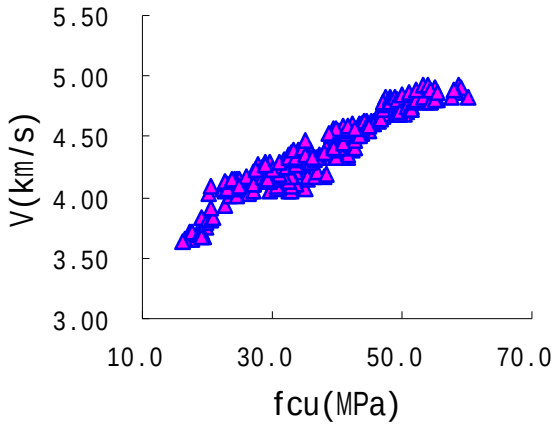

Figure 2. Correlation of the ultrasonic velocity and the compressive strength.

PROCESSING OF TESTING DATA

According to *'Technical Specification For Detecting Strength Of Concrete By Ultrasonic-rebound Combined Method '*,the regression equation of strength curve uses the Eq. 1:

$$f_{cu}^{c} = a v_m^{\ b} R_m^{\ c} \quad (1)$$

Undetermined coefficients of this regression equation are,according to the data of R_m,V_m and f_{cu}(MPa) measured by specimens,counted by the least squares principle.By calculation,the final results are:a= 0.024,b=0.410,c=1.825.

The established ultrasonic-rebound curve equation in Hengyang is:

$$f_{cu}^{c} = 0.024 v^{0.410} R^{1.825} \quad (2)$$

In order to verify the validity of the regression curve to the above data,the relative error and the correlation coefficient should be figured out and the results show that the curve equation has a good representativeness for the data.

The relative error calculation formula is:

$$e_r = \sqrt{\frac{\sum_{i=1}^{n}\left(\frac{f_{cu,i}^{0}}{f_{cu,i}^{c}} - 1\right)^2}{n}} \times 100\% = 4.7\% \quad (3)$$

Where: e_r= relative error, $f_{cu,i}^{0}$ = the compressive strength measured value(MPa) of the i'th cube specime, $f_{cu,i}^{c}$ = the strength deductive value(MPa) of the i'th specimen calculated by the curve equation.

VERIFICATION TEST

Specimens verification

In order to further test the applicability of the regression equation,the concrete specimens which existed in Hengyang construction engineering quality test center's daily inspection work have been verified.Three groups,a total of 27 pieces,were randomly chosen from every strength grade of C20,C25 and C30,three ordinary concrete grades, and the age was 28d.They were selected to take the ultrasonic rebound test and the compression strength test,and then,the ultrasonic velocity value V and the rebound value R measured by these tests can be substituted into the regression equation to calculate compressive strength estimative value and compare this value with compressive strength value of the cubes to count the relative error.Finally,through the comparison and analysis of the relative error calculated by the unified national strength curve and the fitted curve in this article,the consequences are listed on the Table 2:

Table 2. The error comparison between the unified national curve and the fitting curve.

Curve	Deviation of the estimative value and the measured value （%）	Mean variation （%）	Relative standard error （%）
Unified national curve	-30.2 to -6.2	-14.6	19.7
Fitted curve in the article	-17.4 to 8.7	-1.3	6.3

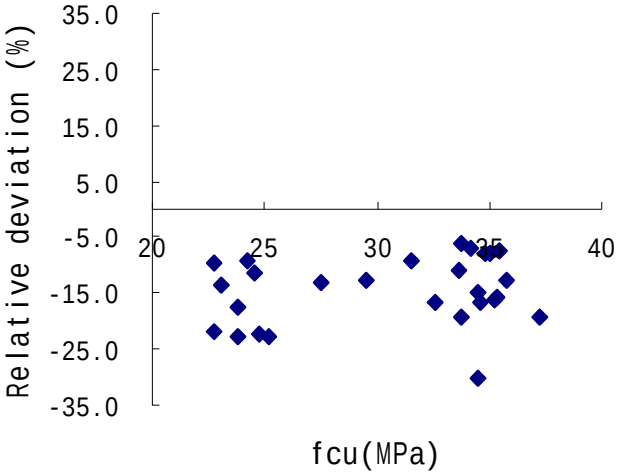

Figure 3. The relative deviation of equivalent value calculated by the unified national strength curve.

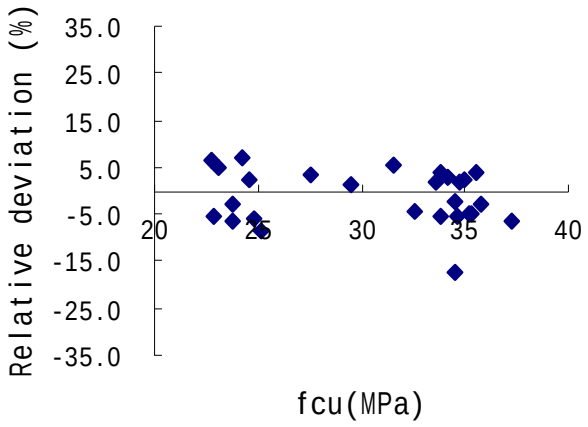

Figure 4. The relative deviation of equivalent value calculated by the fitted curve in this article.

Through the above validation test of concrete specimens and each error calculated by all the conditions in the table,the conclusion can be drawn as follows:

(1)The unified national curve formula is not suitable for counting the concrete ultrasonic rebound conversion value in Hengyang area,because its relative standard error(e_r) and average relative error(δ) can't meet the requirements stipulated by the specification.

(2)If using the unified national strength curve to assess concrete strength,the strength value is 6%-30% smaller than the actual strength value,and the average is 14.6%.It is visible that the evaluation result is much more conservative if using the unified national strength curve to assess concrete strength.

(3)When using the fitting formula to count the concrete ultrasonic rebound conversion value, both relative standard error(e_r) and average relative error(δ) can meet the needs presented by the specification.

Core sample strength verification

In the pumping concrete structure strength test of a certain commercial and residential building project and a certain box culvert project engineering in Hengyang,investigators proceeded not only the core tests,but also the ultrasonic rebound synthetic method tests,and made a contrast test.First, select 10 test area among the components of drill core samples,and determine the springback value of the area for each test individually.Then, measure the ultrasonic wave velocity of each test area, and substitute the measured sonic value 'v' and springback value'R' into the unified national curve and the fitting regression equations in this paper to calculate the mean strength of the artifact in all the test area.At last,compare the average strength value with the mean strength value of drill core samples to calculate the relative standard error.The relative deviation of equivalent value calculated

are shown on the Figure 5 and Figure 6.

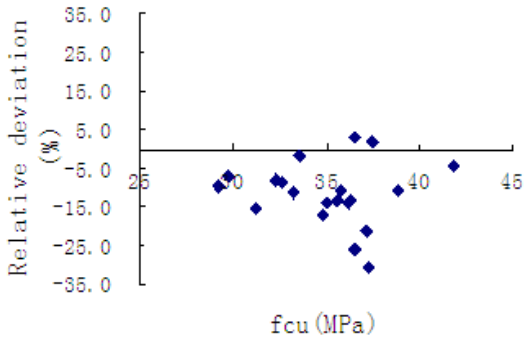

Figure 5. The relative deviation of equivalent value calculated by the unified national strength curve.

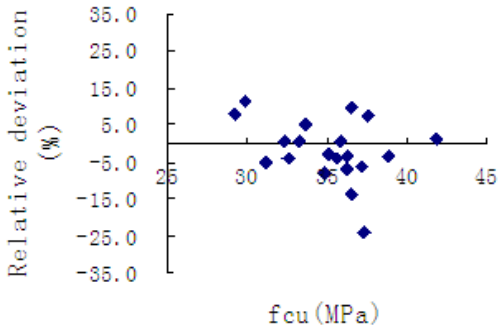

Figure 6. The relative deviation of equivalent value calculated by the fitted curve in this article.

On the basis of the measured results,the relative error of the fitted curve is 9.6% which is smaller than the national unified strength curve whose relative error is 18.1%.What's more,the error of the former curve is under 14%,which satisfies the standard requirements.The strength error of the fitting curve is far less than that of the unified national strength curve,and the former results are closer to the measured compressive strength of core samples.

CONCLUSION

(1)The result shows that the error is lager when using the unified national strength curve to evaluate the concrete strength of new construction in Hengyang.

(2)According to the experimental data of concrete configured by a kind of widely used material in Hengyang area,thesuitable ultrasonic rebound strength curve fitted by least square method is:

$$(4)\quad f_{cu}^{c} = 0.024v^{0.410}R^{1.825}$$

(3)The standard specimens,the field strength detection and strength verification test of core samples on the established strength curve were conducted to verify the accuracy and reliability of the fitting curve equation.

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REFERENCE

[1] CECS 02: 2005 , Technical Specification For Detecting Strength Of Concrete By

Ultrasonic-rebound Combined Method[S].China.

[2] CECS 03: 2007， Technical Specification For Testing Concrete Strength With Drilled Core[S]. China.

[3] Min Du. 2015.The Necessity of The Entry Structure of Civil Engineer Quality Inspection. Jiangxi Building 15(2):247-248. China.

[4]Ping Qiu . 2006.Special or Region Strength Curve Used in Concrete Strenth Test. Construction Technology:35(8).China,

[5]Zheng-quan Ye& Dan Xie. 2012.Study of Ultrasonic Rebound Curve of Panzhihua Area Based on Synthetic Method. Journal of Sichuan univercity of science&Engineering(Natural Science Edition) 25(5):65-69. China.