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No.2724/UN18.F6/EP/2023

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Pangkat/ Golongan	: Pembina/ IV a

Pernah menjadi reviewer pada Jurnal Internasional Bereputasi seperti yang disebutkan dibawah ini.

No.	Judul Article	Nama Jurnal	Status Jurnal
1.	**A novel intelligent rebound hammer system based on the Internet of Things** (*Mei 2022*)	**Macromachines** Publisher: Mulitidisiplinary Digital Publishing Institute (MDPI)	**Q2** SJR 0.58
2	**Crack Depth Loss of Concrete Broken by High Voltage Pulse Discharge Based on Orthogonal Design** (*September 2020*)	**Journal of Advanced Concrete Technology** Publisher : Japan Concrete Institure (JCI)	**Q1** SJR 0.96
3	**Flexural Strength of Modified Reactive Powder Concrete One Way Slabs** (*November 2019*)	**The Open Civil Engineering Journal** **Publisher:** Bentham Science	**Q3** SJR 0.26

Demikian surat keterangan ini dibuat untuk dapat dipergunakan sebagaimana mestinya.

Mataram, April 2023
Dekan,

Muhamad Syamsu Iqbal, ST., MT., Ph.D.
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REVIEW JURNAL 1

Ni Nyoman Kencanawati <nkencanawati@unram.ac.id>

[JACT] Reviewer Invitation for Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design

1 pesan

ACT secretary <em@editorialmanager.com> 5 September 2020 pukul 08.32
Balas Ke: ACT secretary <secretary@j-act.org>
Kepada: Ni Nyoman Kencanawati <nkencanawati@ts.ftunram.ac.id>

Dear Kencanawati,

You have been invited to review a manuscript for Journal of Advanced Concrete Technology.

I would be grateful if you would review a paper entitled "Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design" for this journal.

This is the abstract:
High pulse discharge breakage is a novel crushing method that relies on high electric pulse energy to damage to concrete, the potential of the technology to improve the comminuting effect, but the breaking effect is not fully understand. In this study based on orthogonal design, 27 indoor experiments of high voltage pulse discharge breaking concrete and measurement of crack depth loss of concrete on three factors such as applied voltage, pulse number and discharge electrodes gap were carried out at three levels. The results show that the effects of these three factors on the crack depth loss of concrete are applied voltage, pulse number and discharge electrodes gap in order from large to small. These results can provide some references for engineering technology and defense engineering design to improve the efficiency of concrete target breaking.

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The manuscript reference is 4605.

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With kind regards

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Reviewer Recommendation and Comments for Manuscript Number 4605

Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design

Original Submission
Ni Nyoman Kencanawati Reviewer 2

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Recommendation: Major Revision

Custom Review Question(s):	Response
General Assessment	Good
Originality	
Technical quality	Fair
Contribution to the field	Good
Organization of material	Good
Clarity of presentation	Fair
Grammar and spelling	Good
Questionnaire	Yes
Title Precise and best reflects of the subject matter	
Abstract Represents concise statement of principal findings and conclusions	No
Body text Sections are arranged in a convincing and understandable flow	Yes
Illustrations Sufficient, clear and self-representing illustrations are given	Yes
Tables Concise, readable, understandable and of adequate importance	Yes
Conclusions Significant implications of the manuscript information are included	No

Reviewer Comments to Author

1. Please refer more papers which discuss the fracture failure due to high electrical discharge especially to concrete material and its application in concrete to enrich the literature review
2. The experiment method and the equipment need more explanation (refer to the attachment reviewed manuscript)
3. The concrete has been designed as the quality of C45, however, the actual compressive strength was very low.
4. This paper discusses the effect of high voltage electrical discharge on the crack depth of concrete in which emphasizes the most influential factors using inferential statistics. It has been observed that the applied voltage was the most significant factor that affects the crack depth. It is necessary to provide some discussions on the fracture or damage mechanism that occurs inside concrete due to applied voltage to support the orthogonal experiment conclusion. Simultaneously, it is recommended to compare the mechanism of the crack depth occurrence influenced by other parameters used in this paper.
5. The abstract and the conclusion are also modified according to the requested additional discussions

Reviewer Confidential Comments to Editor:

This paper discusses the effect of high voltage electrical discharge on the crack depth of concrete in which emphasizes the most influential factors using inferential statistics. It has been observed that the applied voltage was the most significant factor that affects the crack depth. However, the conclusion is not supported by the analysis of how the applied voltage generates the crack significantly and the development of crack depth inside the concrete due to applied voltage compared to other parameters. Therefore, it is necessary to provide some discussions on the fracture or damage mechanism that occurs inside concrete to support the orthogonal experiment conclusion. Additionally, I recommend writing down the in terms of the damage process on the paper for a more extensive discussion.

Attachments:

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Journal of Advanced Concrete Technology

Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design

--Manuscript Draft--

Manuscript Number:	4605
Article Type:	Scientific Paper
Full Title:	Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design
Abstract:	High pulse discharge breakage is a novel crushing method that relies on high electric pulse energy to damage to concrete, the potential of the technology to improve the comminuting effect, but the breaking effect is not fully understand. In this study based on orthogonal design, 27 indoor experiments of high voltage pulse discharge breaking concrete and measurement of crack depth loss of concrete on three factors such as applied voltage, pulse number and discharge electrodes gap were carried out at three levels. The results show that the effects of these three factors on the crack depth loss of concrete are applied voltage, pulse number and discharge electrodes gap in order from large to small. These results can provide some references for engineering technology and defense engineering design to improve the efficiency of concrete target breaking.

Crack depth loss of concrete broken by high voltage pulse discharge based on orthogonal design

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Abstract

High pulse discharge breakage is a novel crushing method that relies on high electric pulse energy to damage to concrete, the potential of the technology to improve the comminuting effect, but the breaking effect is not fully understand. In this study based on orthogonal design, 27 indoor experiments of high voltage pulse discharge breaking concrete and measurement of crack depth loss of concrete on three factors such as applied voltage, pulse number and discharge electrodes gap were carried out at three levels. The results show that the effects of these three factors on the crack depth loss of concrete are applied voltage, pulse number and discharge electrodes gap in order from large to small. These results can provide some references for engineering technology and defense engineering design to improve the efficiency of concrete target breaking.

Keywords: High voltage pulse discharge cracking, crack depth loss, orthogonal test, regression analysis, concrete, defense works

1. Introduction

Concrete is the most widely used material in civil construction facilities, defense engineering, and etc. At present, the main breaking modes of concrete were mechanical breaking, ejection shock wave breaking, high pressure water jet breaking etc. (Ulsen *et al.* 2019; Moradloo *et al.* 2019; Rooholamini *et al.* 2019; Fu *et al.* 2006). However, with the rapid development of science and technology, as well as the pursuit of breakage controllable and environmentally friendly breakage technology, a new concrete breakage technology is urgently needed to meet these needs. The technology of concrete broken by high voltage pulse discharge was developed a new technology in the past 20 years. Unlike the previous breaking methods, the technology of concrete broken by high voltage pulse discharge uses the mechanical effects of shock wave, jet or plasma channel produced by pulse discharge to break concrete (Shi *et al.* 2014; Bluhm 2006; Cho *et al.* 2016). Due to the process of concrete broken by high voltage pulse discharge is complex and there are many factors affecting its breakage effect, the mechanism of concrete broken by high voltage pulse discharge is not clear.

In order to improve the research on the mechanism of concrete breakage by high voltage pulse discharge, many scholars at home and abroad have studied the technology of high voltage pulse discharge breakage. Zhang *et al.* (2012) obtained the relationship between electrical breakdown strength of rock and rock type and thickness through the electrical breakdown experiments of rock in water under high voltage short pulse condition. At the same time, it was found that the electrical breakdown strength of rock was related to its porosity and mechanical properties, and then it was found that the effect of the porosity was the most significant for these factors, and the electrical breakdown strength of rock was inversely proportional to its porosity (Zhang *et al.* 2012). Yan *et al.* (2016) studied the experimental of anthracite coal fragmentation by high voltage electrical pulses with breakdown voltage in the air condition. It was found that the degree of coal fragmentation increased with the increase of breakdown voltage, and the higher breakdown voltage attributed to the generation of more pores and fractures in coal samples, and then effect of high voltage on macropores was more remarkable than other types of pores (Yan *et al.* 2016).

Diao *et al.* (2013) used high voltage pulse technology to crush the circuit board. Compared with the traditional mechanical method, the results showed that the crushing product produced by this method had higher yield of coarse particles and lower yield of fine particles, and the phenomenon of "over-crushing" of the circuit board could be effectively avoided. And then it was found that the relationship between energy consumption and Walker equation in breaking process of high voltage electric pulse had a good correlation (Diao *et al.* 2013). Boev *et al.* (1999) carried out optimizing experiments on concrete and granite breakage by high voltage pulse discharge in water. It was found that the breakage effect of concrete and granite could be adjusted by changing the rising edge of pulse discharge (Boev *et al.* 1999). The results showed that the discharge voltage and the discharge times of the equipment were the two main factors affecting the breaking effect, and it was found that large-sized rocks were more likely to break (van der Wielen *et al.* 2013).

Wang *et al.* (2012a) studied the factors affecting the breakage of high voltage pulse discharge by experiment and numerical simulation methods. The results showed that the breakage effect of high voltage pulse discharge strongly depends on the rock properties. Moreover, the simulation results showed that there was high electric field strength at the interface of two kinds of rocks, and the conductive substances in rocks could change the failure path and effect of rocks (Wang *et al.* 2012a). Li *et al.* (2018) studied the effect of breakdown voltage on the breaking of anthracite coal fragmentation by high voltage electrical pulse. The results showed that the fragmentation degree of anthracite coal increased with the increase of the breakdown voltage, and it was found that the increase of breakdown voltage would increase the volume of voids, cracks and micropores in anthracite coal by using scanning electron microscopy (SEM), low-pressure nitrogen gas adsorption (LP-N2G) and mercury intrusion porosimetry (MIP) (Li *et al.* 2018).

Lin *et al.* (2001) studied the ultrasonic detection method of concrete crack depth by theory and experiment. It was found that the time domain analysis method of impact echo with double receiving transducers could effectively detect concrete crack depth (Lin *et al.* 2001). Kim et al. carried out the research of characterization of the crack depth in concrete using self-compensating frequency response function. The results showed that using self-compensation frequency response function to improve the isolation of Rayleigh wave component and associated noise, and could effectively determine the crack depth. At the same time, the effectiveness of this method was verified by experiments of structural crack and artificial notch (Kim *et al.* 2010). Ogura *et al.* (1997) used low frequency ultra-sound to measure the crack depth of on the surface of concrete members. The corresponding relationship between the crack depth and the ultrasonic propagation time/receiving frequency was obtained by changing the ultrasonic mode, frequency and probe spacing and other basic experiments. The result showed that there was a correlation between the crack depth and the acoustic propagation time/receiving frequency by choosing appropriate ultrasonic mode (Ogura *et al.* 1997).

In conclusion, although some progress has been made in the research on the mechanism of concrete broken by high voltage pulse discharge, there are still many basic scientific issues to be studied, and the crack depth loss is an important index to examine the non-destructive of concrete material. Therefore, this paper aims to clarify some of these aspects of the technology and analysis and optimization of effect result. This is done by investigating the influence of applied voltage, pulse number and discharge electrodes gap on the crack depth loss after high voltage pulse discharge treatment. The focus of this paper is based on orthogonal design, the effects of different applied voltage, pulse number and discharge electrodes gap on the crack depth loss of concrete broken by high voltage pulse discharge are analyzed by indoor experiments. The significant effects of different factors on the crack depth loss of crushing concrete are obtained through the examine method of mathematical modeling. In order to improve the breaking mechanism of rock breakage by high voltage pulse discharge and it can provide some references for engineering technology and defense engineering design to improve the efficiency of concrete target breaking.

2. Methods and Materials

2.1. Experiment system

The schematic diagram of the experimental system of breaking concrete generator by high voltage pulse discharge used in this paper is shown in Figure 1. The experimental system is mainly composed of high voltage power supply, capacitors, discharge switches, breakdown chamber, discharge electrodes, water, concrete target and oscilloscope (Tektronix). The discharge electrodes adopt the needle-needle structure and are installed in the breakdown chamber of high voltage pulse discharge crushing device. One electrode is used as the positive electrode and the other is grounded. The capacity of the capacitor is 5uF. The maximum output voltage of the high voltage pulse discharge generator system is up to 300kV, and the maximum energy output of a single electric pulse is 100J. The breakdown chamber is made of polyethylene material, and the water in the chamber can completely submerge the concrete target.

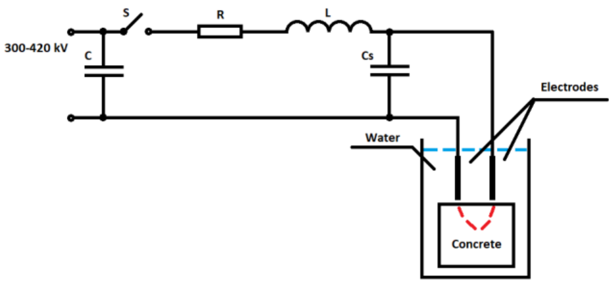

Figure 1. Schematic diagram of experiment system for high voltage pulse discharge crushing concrete generator: C - generator capacitor, S - switch, L - inductor, R - resistance, Cs - stray capacitance. *(Output pulse parameters: - output voltage: 180~420kV (adjustable), - output energy: 13-70.56J, - rise time: <40ns, - duration time: about 240ns, - fall time: about 160ns)*

The schematic diagram of the experimental system for crack depth loss detection of concrete is shown in Figure 2. The experimental system is mainly made up two parts: crack depth detector of concrete and concrete target. The crack depth detector is composed of detector host, plane transducer, signal connecting line, digital display screen and crack sounder scale, etc. Concrete target is the experimental target before and after each high voltage pulse discharge breakage. The crack depth loss of concrete crushed by high voltage pulse discharge is the difference between the value of the crack depth measured before crushing and that measured after crushing

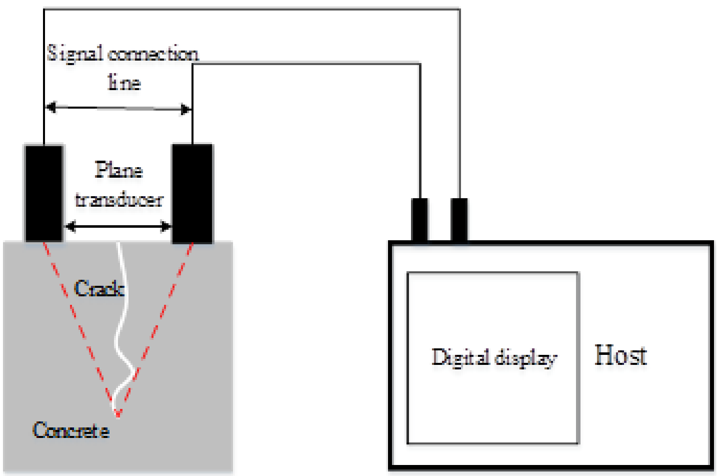

Figure 2. Diagrammatic sketch of experiment system of crack depth detection of concrete

2.2. Experiment preparation

In this experiment, concrete target is self-made square C45 concrete samples with the size is 15cm * 15cm * 15cm, and the mix proportions of cement, fly ash, sand, spall, water and water-reducing admixture are 1:0.43: 2.12:3.93:0.62:0.01 respectively. There are 27 square samples in total in the experiment, and the individual sample is shown in Figure 3. These square concrete samples from self-made were analyzed. Strength analysis of this square concrete sample was conducted according to the Chinese National Standard GB/T50081-2002 guidelines (Ministry of Construction, the State Administration of Quality Supervision, Inspection and Quarantine People's Republic of China 2003). The results from strength analysis of this concrete sample are presented in Table 1.

Figure 3. Individual square concrete samples in the experiment

Table 1. Relevant parameters of concrete sample

Concrete sample grade	Density *P* （kg/m^3）	Weight *m* （kg）	Compressive strength *f* N/mm^2	Elastic modulus *E* N/mm^2
C45	$2.41*10^3$	7.9	21.1	$3.25*10^4$

2.3. Experiment scheme

In this experiment, the factors that affect the crack depth loss of concrete broken by high voltage pulse discharge and the selected working conditions are as follows.

(1) The applied voltage is 324kV, 360kV and 415kV respectively.

(2) The pulse number is 1, 5 and 9 respectively.

(3) The discharge electrodes gap is 3cm, 5cm and 7cm respectively.

According to the above experimental scheme, the main factors considered in the experiment are applied voltage, pulse number and discharge electrodes gap. There are three corresponding levels of these three factors. The level table of these experimental factors for the crack depth loss of concrete broken by high voltage pulse discharge is listed in Table 2.

Table 2. Level table of experimental factors for crack depth loss of concrete broken by high voltage pulse discharge

Factor / Level	Applied voltage (kV)	Pulse number (times)	Discharge electrodes gap (cm)
1	324	1	3
2	360	5	5
3	415	9	7

In this paper, $L_9(3^3)$ orthogonal table is selected for experimental analysis of the crack depth loss of concrete broken by high voltage pulse discharge. Because three factors were considered in the experiment, A, B and C were used to represent the orthogonal experiments of three factors respectively, and the experiment was repeated for three times at different levels of each factor.

In all experiments,presented energy levels refer to the spark switch energy input. When assessing the efficiency of high voltage pulse discharge breakage technology it is advised that the Marx generator energy input is relied upon, but for the research is preferred as it leaves out of the equation device-specific influence and discharge inefficiencies.

3. Results

According to the combination modes of table 3, experiment of concrete broken by high voltage pulse discharge and measurement experiment of the crack depth are carried out. The results of the crack depth loss of breaking concrete are shown in Table 3.

Table 3. Orthogonal experiment table and experiment results of crack depth loss of $L_9(3^3)$ crushing concrete.

Experiment number	Level of each factor			Crack depth loss（mm）	Mean value of crack depth loss（mm）
	A Applied voltage (kV)	B Pulse number (times)	C Discharge electrodes gap (cm)		
1	324	1	3	11.013	11.250
2	324	1	3	11.476	
3	324	1	3	11.261	
4	324	5	5	49.879	50.583
5	324	5	5	50.314	
6	324	5	5	51.556	
7	324	9	7	26.724	26.583
8	324	9	7	26.362	
9	324	9	7	26.663	
10	360	1	5	1.624	1.500
11	360	1	5	1.478	
12	360	1	5	1.398	
13	360	5	7	4.967	5.083
14	360	5	7	5.145	
15	360	5	7	5.137	
16	360	9	3	33.217	33.333
17	360	9	3	33.104	

18	360	9	3	33.678	
19	415	1	7	32.574	32.917
20	415	1	7	32.758	
21	415	1	7	33.419	
22	415	5	3	23.940	24.168
23	415	5	3	24.112	
24	415	5	3	24.452	
25	415	9	5	3.137	3.167
26	415	9	5	2.912	
27	415	9	5	3.452	

3.1. Range analysis

The range analysis of the experimental results of the crack depth loss of concrete broken by high voltage pulse discharge in Table 3 is carried out. Firstly, the sum of the crack depth loss of concrete of each factor at each level is calculated, and the results are shown in Table 4. Then, the average value of the crack depth loss of concrete of each factor at each level is calculated, and the results are shown in Table 5.

From the definition of range, the range is the difference between the maximum value and the minimum value of the average value of the crack depth loss of concrete of each factor. This index indicates the change of the crack depth loss of concrete under the action of a certain factor, that is, That is, the influence of this factor on the crack depth loss. From the range value of Table 5, it can be seen that the range value of the applied voltage is the largest, followed by the pulse number, and finally the discharge electrodes gap. Therefore, among the three factors, the impact of the applied voltage on the crack depth loss of concrete broken by high voltage pulse discharge is the greatest, followed by the pulse number, and finally the gap between positive and negative electrodes.

Table 4. Sum of crack depth loss of concrete at different levels

Factor	Sum of the crack depth loss at different levels (mm)		
	1	2	3
A(Applied voltage)	88.416	39.916	60.252
B (Pulse number)	45.667	79.834	63.083
C(Discharge electrodes gap)	68.751	55.250	64.583

Table 5. Average and range of crack depth loss of concrete at different levels

Factor	Average value of the crack depth loss at different levels (mm)			Range (mm)
	1	2	3	
A(Applied voltage)	29.472	13.305	20.084	16.167
B (Pulse number)	15.222	26.614	21.028	11.392
C(Discharge electrodes gap)	22.917	18.417	21.528	4.500

In order to make a more intuitive comparison, the crack depth loss of concrete crushed by high voltage pulse discharge under different levels of each factor drawn from Table 5 is shown in Figure 4. From Figure 4, it can be concluded that:

(1) For the applied voltage factor, the crack depth loss of concrete crushed by high voltage pulse discharge is the greatest at 324kV (A_1).

(2) For the pulse number factor, the crack depth loss of concrete crushed by high voltage pulse discharge is the greatest at five times (B_2).

(3) For the discharge electrodes gap, the crack depth loss of concrete crushed by high voltage pulse discharge is the greatest at 3cm (C_1).

Combining the above conclusions, the crack depth loss of crushing concrete under the combination of factors $A_1B_2C_1$ will be the largest.

In order to determine the crack depth loss of concrete crushed by high voltage pulse discharge under condition of combination $A_1B_2C_1$, the experiment is carried out under the condition separately. The experiment result shows that the crack depth loss of concrete broken by high voltage pulse discharge under the combination condition is 37.07mm, which is 25.78% higher than the maximum of the crack depth loss of concrete broken by high voltage pulse discharge in the orthogonal experiment.

From Figure 4, it can be easily seen that the primary and secondary effects of various factors are about the crack depth loss of concrete broken by high voltage pulse discharge. In the figure, if a factor has a great influence on the crack depth loss of crushing concrete, the difference of the crack depth loss of crushing concrete under different levels of this factor will be very large, that is, this factor is the main factor affecting the crack depth loss of crushing concrete. On the contrary, if the difference of the crack depth loss of crushing concrete is very small at different levels of this factor, that is, this factor is the secondary factor affecting the crack depth loss of crushing concrete. The difference of the crack depth loss of concrete crushed by high voltage pulse discharge is reflected in Figure 4 as the distribution of the corresponding points of the crack depth loss.

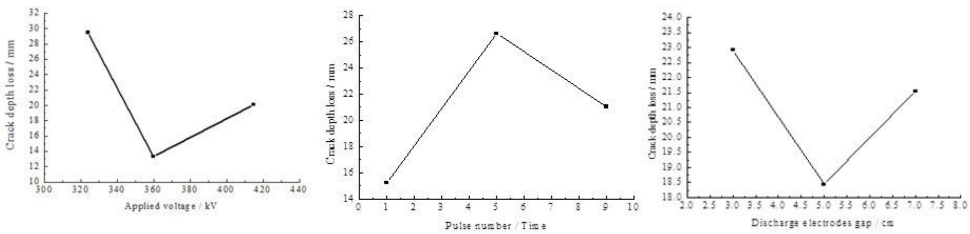

Figure 4. Crack depth loss of concrete under different levels of each factor

According to the above rules, it can be seen from Figure 4 that the point of applied voltage is the most dispersed among all the factors affecting the crack depth loss of concrete crushed by high voltage pulse discharge, so the applied voltage is the main factor affecting the crack depth loss of concrete broken. Secondly, the point of pulse number is more dispersed, so the pulse number is the secondary factor affecting the crack depth loss of concrete broken. Ultimately, it is the distance between discharge electrodes. That is to say, the influence order of these three factors on the crack depth loss of concrete broken by high voltage pulse discharge is the applied voltage, the pulse number and the discharge electrodes gap. Through the previous analysis, it is found that the change of the crack depth loss of concrete crushed by high voltage pulse discharge is different with different factors. In view of this, the crack depth loss of concrete can be increased by adjusting sensitive factors, and the damage of defense works (concrete) can be further improved.

In the experimental system of concrete crushed by high voltage pulse discharge, if the discharge electrodes gap is fixed, the distance between of discharge electrodes can be regarded as a fixed value. Therefore, in the design of demolition of defense works (concrete), the crack depth loss of broken concrete by high voltage pulse discharge can be controlled by adjusting the applied voltage and the pulse number. Under the action of two factors, the maximum of the crack depth loss of concrete is A_1B_2.

Figure 5 shows the change curve of the crack depth loss of concrete broken by high voltage pulse discharge with different applied voltage under the condition that of discharge electrodes gap is 3cm, 5cm and 7cm and pulse number is 5. As can be seen from Figure 5, the crack depth loss of concrete broken decreases firstly and then increases with the increase of the applied voltage. When the applied voltage is 324kV, the crack depth loss is the largest. When applied voltage is 324kV, the crack depth loss of concrete broken increases by 121.5% compared with the smallest crack depth loss of concrete.

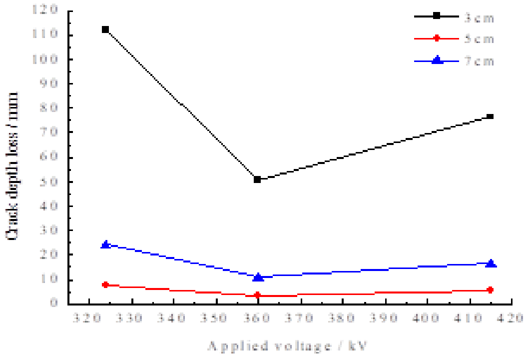

Figure 5. Variation curves of the crack depth loss of concrete under different applied voltages

Figure 6 shows the variation curve of the crack depth loss of concrete broken by high voltage pulse discharge with different pulse number under the condition that of discharge electrodes gap is 3cm, 5cm and 7cm and applied voltage is 360kV. Figure 6 shows that the crack depth loss of concrete broken increases firstly and then decreases with the increase of pulse number. When the pulse number is 5, the crack depth loss of concrete is the largest. When the pulse number is 5, the crack depth loss of broken concrete increases by 74.8%, compared with the minimum crack depth loss.

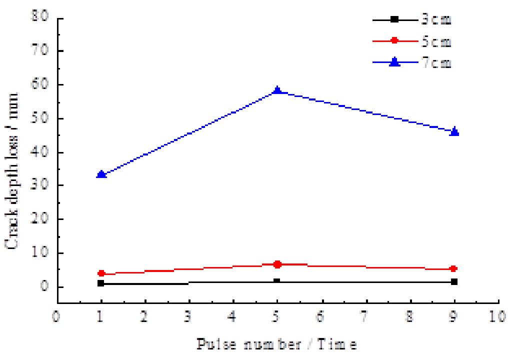

Figure 6. Variation curves of the crack depth loss under different pulse number

3.2. Significance analysis

In order to accurately evaluate the magnitude of the error of experimental results of the crack depth loss of concrete broken by high voltage pulse discharge, and correctly distinguish the data fluctuation caused by experimental errors and the change of experimental conditions. The significance analysis of the influence of these three factors considered in the experiments on the crack depth loss of concrete crushed by high voltage pulse discharge is carried out. According to the method of mathematical statistics, the degree of freedom in Table 6 is equal to the factor level number minus 1; $f_{0.1}$ is the critical value of F test when the significant level is 0.1; $f_{0.1}$ can be obtained by querying the upper sub-table of F distribution. In Table 6, F is the ratio of inter-group variance to intra-group variance, which is called test statistics.

Inter-group variance is

$$S_{Inter-group} = \sum_{i=1}^{a} n_i \left(\overline{y_i} - \overline{y} \right)^2 \quad (1)$$

Where a is the number of factors considered; n_i is the number of experimental data under the factor i; y_i is the experimental value under the factor i; $\overline{y_i}$ is the average of experimental data under the factor i; and $\overline{y}$ is the average of the whole experimental results.

Intra-group variance is

$$S_{Intra-group} = \sum_{i=1}^{a} \sum_{j=1}^{n_i} n_i \left(y_{ij} - \overline{y} \right)^2 \quad (2)$$

Where y_{ij} is the experimental value of each experiment.

The test statistic F is

$$F = \frac{S_{Inter-group}}{S_{Intra-group}} \quad (3)$$

After calculating the test statistic F, the significance of each factor can be judged by comparing it with the test critical value. When the F value is greater than $f_{0.1}$, it means that this factor has a significant effect on the experimental results; on the contrary, it means that the influence is not significant. The results of the crack depth loss of concrete broken by high voltage pulse discharge through F test are shown in Table 6.

Table 6. Significance analysis table

Factor	Freedom	$f_{0.1}$	F value	Significance
A(Applied voltage)	2	9	10.8	Notable
B (Pulse number)	2	9	5.4	
C(Discharge electrodes gap)	2	9	0.9	

From Table 6, it can be seen that the impact of the applied voltage on the crack depth loss of concrete crushed by high voltage pulse discharge is obvious and it has a certain decisive role, and then followed by the pulse number, while the effect of the discharge electrodes gap on the crack depth loss of concrete crushed is weak.

4. Discussions

As initially expected, the results of this research demonstrated that the effect of high voltage pulse discharge on concrete crushing can be studied from the angle of crack depth loss. This is unlike previous research where analysis of crushing effect was from breakage mass change (Wang *et al.* 2012b), breakage probability (Zuo *et al.* 2015a), breakage crack width (Wang *et al.* 2011), breakage volume (Vazhov *et al.* 2011; Boev *et al.* 2000), breakage size (Lastra *et al.* 2003; Shi *et al.* 2013, 2015; Zuo *et al.* 2015b; Andres *et al.* 2001), crack number (Sun *et al.* 2014), breakage hardness change (Wang *et al.* 2011) and etc.

It was also noticed that the applied voltage, the pulse number and the discharge electrodes gap all had a certain extent effect on the crack depth loss of concrete broken by high voltage pulse discharge, and the order of these three factors was the applied voltage, the pulse number and the discharge electrodes gap. This is logical because some previous researches have been conducted on voltage, pulse number or discharge spacing. The research results of Shi *et al.* (2013) showed when the voltage was 180kV, the pre weakening degree of ore could be 80.9% by one discharge, and the pre-weakening degree decreases first and then increased with the increase of pulse number, which was not a linear relationship (Shi *et al.* 2013). Sun *et al.* (2014) demonstrated for proportion of cement to sand is 1:1, the height and number of cracks hardly changed with the increase of applied voltage under one dischrge (Sun *et al.* 2014). Kovalchuk *et al.* (2013) found that under the same conditions, increasing the pulse number could effectively crush concrete and granite, but no specific relationship was given (Kovalchuk *et al.* 2013). Vazhov *et al.* (2012) only discovered the effect of high voltage pulse discharge on the crushing of granite and concrete was affected to some extent by applying volitage and different electrodes (Vazhov *et al.* 2012). Inoue *et al.* (1999) obtained destructive characteristics of granite were influenced by pulse (energy) effectiveness, applied voltage and electrode spacing (Inoue *et al.* 1999). Zuo *et al.* (2015c) proposed all kinds of operation conditions had influence on ore crushing behavior. However, the ore properties had a significant impact on the high voltage pulse crushing performance (Zuo *et al.* 2015c). Based on the above discussion, the research is suggested that the parameters of apply voltage, pulse number and electrode spacing should be optimized.

It was noted that the distance of discharge electrodes was fixed in the process of breaking concrete by high voltage pulse discharge, therefore, it was only necessary to analyze the influence of applied voltage and pulse number on concrete crushing by high voltage pulse. Through the significance analysis, i.e. F test, we found that the impact of the applied voltage on the crack depth loss of concrete crushed by high voltage pulse discharge was very significant.

5. Conclusions

The purpose of this research was to analyze the effects of different applied voltage, pulse number and spacing of discharge electrodes on the crack depth loss of concrete broken by high voltage pulse discharge.

Orthogonal experiments show that the applied voltage and the pulse number have an obvious effect on the crack depth loss of concrete broken by high voltage pulse discharge. The order of these three factors is the applied voltage, the pulse number and the discharge electrodes gap.

Because the distance of discharge electrodes is fixed in the process of breaking concrete by high voltage pulse discharge, the crack depth loss of concrete broken can be controlled by changing the applied voltage and the pulse number value. Under the action of these two factors, the combination of A_1B_2 is the largest. Adjusting the applied voltage and pulse number value can increase by about 121.5% and 74.8% of the crack depth loss of concrete broken respectively.

Significance analysis based on *F* test shows that the impact of the applied voltage on the crack depth loss of concrete crushed by high voltage pulse discharge is very significant.

Results of this research will provide a theoretical basis for the effect of high voltage pulse discharge on concrete crushing and the optimization of circuit parameters. The next step work is to study the crack change concrete breakage of by high-voltage pulse discharge from the microscopic point of view.

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References

Andres, U., Timoshkin, I., Jirestig, J. and Stallknecht, H., (2001). "Liberation of valuable inclusions in ores and slags by electrical pulses". *Powder Technology,* 114 (1-3), 40-50.

Bluhm, H., (2006). "*Power Systems"*. Berlin: Springer.

Boev, S., Vajov, V., Jgun, D. and Kalyatskii, I., (2000). "Reasearch of conditions of material destruction by electric pulse discharges". *Proceedings KORUS 2000. The 4th Korea-Russia International Symposium on Science and Technology,* 3, 346-349.

Boev, S., Vajov, V., Jgun, D., Levchenko, B., Muratov, V., Adam, A. and Uemura, K., (1999). "Destruction of granite and concrete in water with pulse electric discharges". *Digest of Technical Papers. 12th IEEE International Pulsed Power Conference. (Cat. No. 99CH36358),* 2, 1369-1371.

Cho, S. H., Cheong, S. S., Yokota, M. and Kaneko, K., (2016). "The dynamic fracture process in rocks under high-voltage pulse fragmentation". *Rock Mechanics and Rock Engineering,* 49 (10), 3841-3853.

Diao, Z., Zhao, Y., Duan, C., Sun, S. and Xu, F., (2013). "Fundamental study of fragmentation of waste printed circuit boards by a high voltage pulse". *Journal of China University of Mining & Technology, 42*(05), 817-823.

Fu, S., Li, H. T., Li-li, L. I. U. and Shi, Z. Y., (2006). "Cavitating water jet formation techniques and their application". *Mechanical Science and Technology,* 25 (4), 491-495.

Inoue, H., Lisitsyn, I. V., Akiyama, H. and Nishizawa, I., (1999). "Pulsed electric breakdown and destruction of granit"e. *Japanese journal of applied physics,* 38 (11R), 6502-6505.

Kim, J. H., Kwak, H. G. and Min, J., (2010). "Characterization of the crack depth in concrete using self-compensating frequency response function". *NDT & E International,* 43 (5), 375-384.

Kovalchuk, B. M., Kharlov, A. V., Kumpyak, E. V. and Sinebrykhov, V. A., (2013). "High-voltage pulsed generators for electro-discharge technologies". *Journal of Instrumentation,* 8 (09), 1-18.

Lastra, R., Cabri, L. J., Weiblen, P. W., Lorenzen, L. and Bradshaw, D. J., (2003). "Comparative liberation study by image analysis of Merensky reef samples comminuted by electric-pulse disaggregation and by conventional crusher". *Proceedings of the XXII International Mineral Processing Congress,* 1, 251-260).

Li, C., Duan, L., Tan, S. and Chikhotkin, V., (2018). "Influences on high-voltage electro pulse boring in granite". *Energies,* 11 (9), 2461.

Lin, W., Su, Y. and Hong, Y., (2001). "Ultrasonic testing methods for the depth of concrete crack". *Nondestructive Testing,* 23 (8), 323-326.

Ministry of Construction, the State Administration of Quality Supervision, Inspection and Quarantine People's Republic of China, (2003). "*GB/T50081-2002 Standard for test method of mechanical properties on ordinary concrete"*. Beijing: China Standard Press.

Moradloo, A. J., Adib, A. and Pirooznia, A., (2019). "Damage analysis of arch concrete dams subjected to underwater explosion". *Applied Mathematical Modelling,* 75, 709-734.

Ogura, Y., Miyajima, T., Takishita, T., Ohtake, K. and Akutsu, Y., (1997). "Measurement of crack depths in concrete". *NDT and E International,* 4 (30), 265.

Rooholamini, H., Sedghi, R., Ghobadipour, B. and Adresi, M., (2019). "Effect of electric arc furnace steel slag on the mechanical and fracture properties of roller-compacted concrete". *Construction and Building Materials,* 211, 88-98.

Shi, F., Manlapig, E. and Zuo, W., (2014). "Progress and challenges in electrical comminution by high- voltage pulses". *Chemical Engineering & Technology,* 37 (5), 765-769.

Shi, F., Zuo, W. and Manlapig, E., (2013). "Characterisation of pre-weakening effect on ores by high voltage electrical pulses based on single-particle tests". *Minerals Engineering,* 50, 69-76.

Shi, F., Zuo, W. and Manlapig, E., (2015). “Pre-concentration of copper ores by high voltage pulses. Part 2: Opportunities and challenges”. *Minerals Engineering*, 79, 315-323.

Sun, Y., Zhou, J., Fu, R., Gao, Y., Yan, P. and Jiang, T., (2014). “Experimental study on rock fracturing by using pulsed power technology”. *2014 IEEE International Power Modulator and High Voltage Conference (IPMHVC)*, 229-232.

Ulsen, C., Tseng, E., Angulo, S. C., Landmann, M., Contessotto, R., Balbo, J. T. and Kahn, H., (2019). “Concrete aggregates properties crushed by jaw and impact secondary crushing”. *Journal of Materials Research and Technology*, 8 (1), 494-502.

van der Wielen, K. P., Pascoe, R., Weh, A., Wall, F. and Rollinson, G., (2013). “The influence of equipment settings and rock properties on high voltage breakage”. *Minerals Engineering*, 46, 100-111.

Vazhov, V. F., Gafarov, R. R., Datskevich, S. Y., Zhurkov, M. Y., Lopatin, V. V., Muratov, V. M. and Jeffryes, B., (2011). “Breakage of rocks by pulsed electric discharge at elevated pressures and temperatures”. *Technical Physics Letters*, 37 (4), 383-386.

Vazhov, V. F., Muratov, V. M., Levchenko, B. S., Peltsman, S. S., Zhgun, D. V. and Adam, A. M., (2012). “Rock breakage by pulsed electric discharges”. *Journal of Mining Science*, 48 (2), 308-313.

Wang, E., Shi, F. and Manlapig, E., (2011). “Pre-weakening of mineral ores by high voltage pulses”. *Minerals Engineering*, 24 (5), 455-462.

Wang, E., Shi, F. and Manlapig, E., (2012a). “Factors affecting electrical comminution performance”. *Minerals Engineering*, 34, 48-54.

Wang, E., Shi, F. and Manlapig, E., (2012b). “Mineral liberation by high voltage pulses and conventional comminution with same specific energy levels”. *Minerals Engineering*, 27, 28-36.

Yan, F., Lin, B., Zhu, C., Zhou, Y., Liu, X., Guo, C. and Zou, Q., (2016). “Experimental investigation on anthracite coal fragmentation by high-voltage electrical pulses in the air condition: Effect of breakdown voltage”. *Fuel*, 183, 583-592.

Zhang, Z., Pei, Y., Liu, Z., Wang, K., Liu, B. and Yan, K., (2012). “Experimental research on rock breakdown under short high-voltage pulse”. *High Voltage Engineering*, 38 (7), 1719-1725.

Zuo, W., Shi, F. and Manlapig, E., (2015a). “Modelling of high voltage pulse breakage of ores”. *Minerals Engineering*, 83, 168-174.

Zuo, W., Shi, F. and Manlapig, E., 2015b. “Pre-concentration of copper ores by high voltage pulses. Part 1: Principle and major findings”. *Minerals Engineering*, 79, 306-314.

Zuo, W., Shi, F., van der Wielen, K. P. and Weh, A., 2015c. Ore particle breakage behaviour in a pilot scale high voltage pulse machine. *Minerals Engineering*, 84, 64-73.

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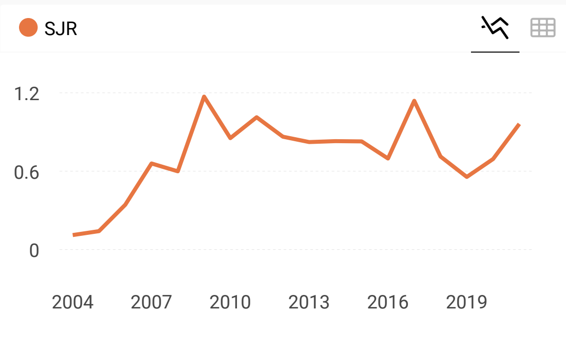

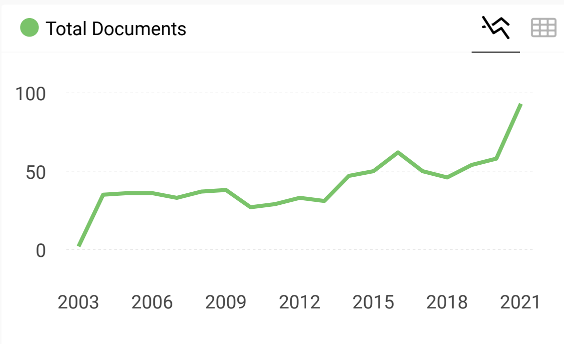

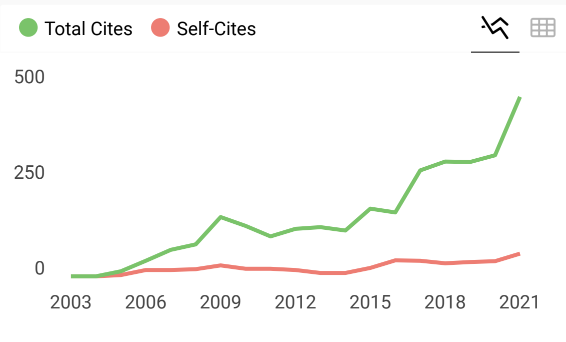

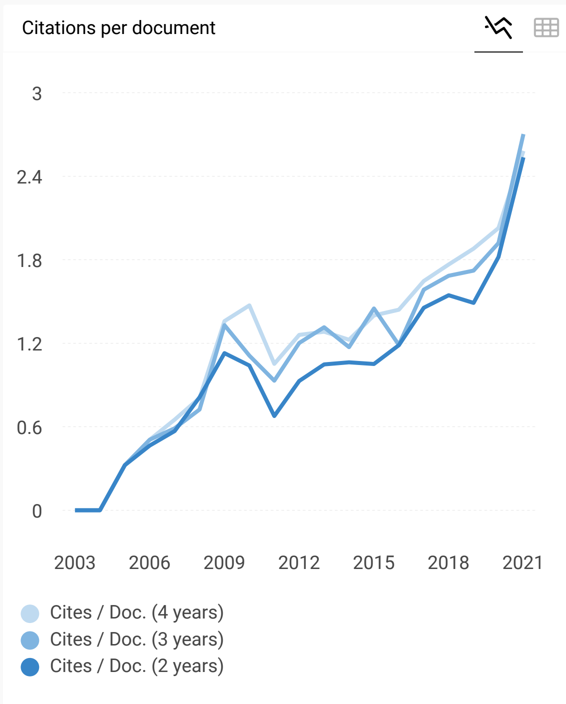

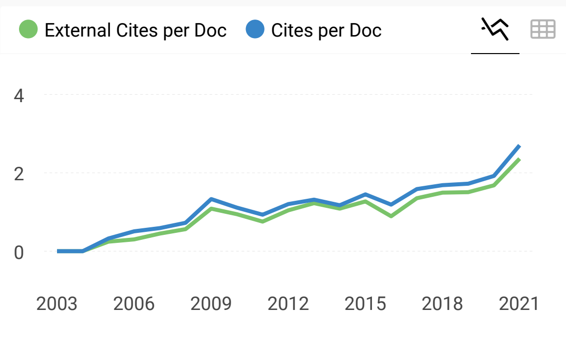

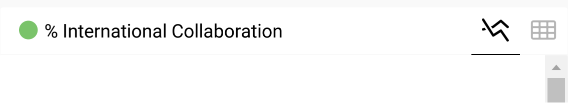

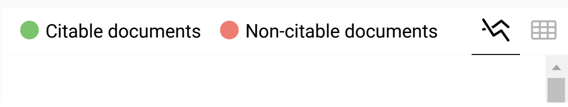

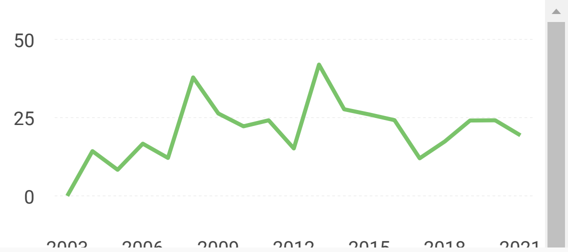

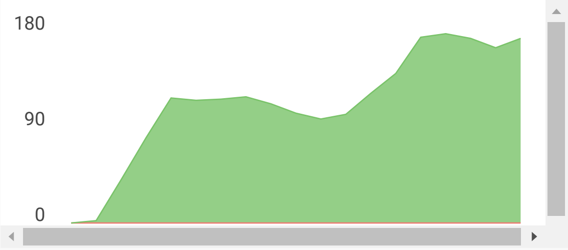

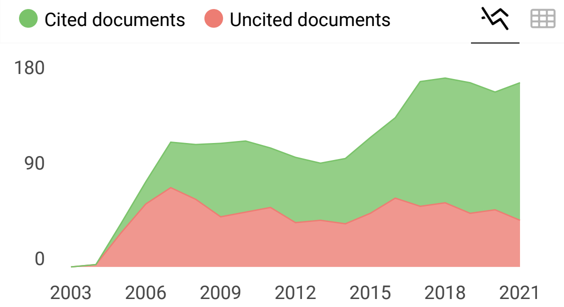

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Abstract: In order to improve the test efficiency of concrete strength and ensure the measured data reliability, we design a novel intelligent rebound hammer system which is based on Internet of Things (IoT) and speech recognition technology. The system uses a STM32F103C8T6 microcontroller as the Main Control Unit (MCU), and one BC26 module as the communication unit, combined with LD3320 voice recognition module and TOF050H laser ranging sensor to achieve the function of phonetic transcription and laser ranging. Without the need of traditional multi-person collaboration and burdensome data transferring, the system can collect the data of rebound value and location information, and send them to the remote cloud information management system automatically in real time. The test results show that the system has high measuring accuracy, good data transmission stability and convenient operation, which could may provide guidance for other types of non-destructive testing equipment designing.

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Abstract: In order to improve the test efficiency of concrete strength and ensure measured data reliability, we present a novel intelligent rebound hammer system which is based on the Internet of Things (IoT) and speech recognition technology. The system uses a STM32F103C8T6 microcontroller as the Main Control Unit (MCU), and one BC26 module as the communication unit, combined with a LD3320 voice recognition module and TOF050H laser ranging sensor to achieve the function of phonetic transcription and laser ranging. Without the need for traditional multi-person collaboration and burdensome data transfer, the system can collect the data of rebound value and location information and send them to the remote cloud information management system automatically in real time. The test results show that the system has high measuring accuracy, good data transmission stability and convenient operation, which could provide guidance for other types of non-destructive testing equipment designs.

Keywords: rebound hammer; internet of things; laser ranging; phonetic transcription; cloud platform

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1. Introduction

The strength of concrete is related to the safety of the main structure of a building; it is the most important part of quality control of a cast-in-place concrete structure. However, during the actual construction process, construction safety accidents often occur due to misoperation by front-line staff or inadequate supervision from managers, both of which have caused huge economic losses. The testing methods of concrete strength can be divided into destructive and nondestructive testing. The destructive testing method, which involves drilling a cylindrical sample from the main structure and testing it inside the laboratory, has higher measurement accuracy but comes with high costs and is time-consuming. Most importantly, the method may cause irreparable damage to the concrete structure, which makes it unusable for some important concrete structures or other important projects with special requirements.

The nondestructive testing method does not impair the building structure and allows for re-testing at the same location to compare the changes in concrete quality. As the concrete is susceptible to a variety of environmental degrading factors which tend to limit its service life, concrete strength should be tested in situ periodically for quality assurance and the evaluation of existing conditions [1]. Among the many nondestructive testing methods, such as ultrasonic pulse velocity [2], ray absorption and scattering, the rebound hammer and the ultrasonic-rebound combined method, the rebound hammer is deemed as the most popular method for concrete quality testing, which is popular for its simple structure, ease of use and low cost [3,4]. The basic principle of the rebound hammer is to use the spring-driven heavy hammer to make the heavy hammer hit the impact bar that is in vertical contact with the concrete surface with constant kinetic energy in order that the local concrete deforms and absorbs part of the energy. The other part of the energy will be converted into the rebound kinetic energy of the heavy hammer. When all the rebound kinetic energy is converted into potential energy, the heavy hammer will rebound to a maximum distance. The rebound number is the ratio of the maximum springback distance to the initial spring length. According to the JGJ/T 23-2011, the rebound hammer uses the rebound number which is related to the surface hardness of the concrete to evaluate the strength of the concrete [5].

Most early rebound hammers involve contact measuring and require manual reading and recording of its rebound value. Due to the friction of the pointer during application, some metal powder may attach to the resistors, which will affect the sensitivity of the sensor, so this type of rebound hammer has lower efficiency and a short lifespan [6]. In order to settle the friction problem, Shejiao's team developed one intelligent rebound hammer system which uses linear CCD imaging as the non-contact rangefinder sensor to measure the displacement of the hammer; the MCU is used for circuit driving and image processing back in the office after the test and transfers all the measured data to the computer through a USB port [7]. In 2007, they developed another intelligent rebound hammer system which was based on PSD and Zigbee technology and which achieved non-contact range-finding and wireless data transmission [8]. However, for the location information of the test area, it still requires another surveyor to record synchronously. Moreover, limited by weak diffraction, weak signal penetration and the requirement of an ad hoc network for Zigbee technology, it is not convenient for use in actual construction sites [9].

In this paper, we present one novel intelligent rebound system which is based on IoT and speech recognition technology [10]. Using laser ranging sensor to measure the hammer displacement and a voice recognition module to record the location information under testing, the MCU collects the data and sends them to the remote cloud information management system by the IoT module in real time [11]. There is no need for traditional multi-person collaboration and burdensome data transfer. Most importantly, it avoids the risks of artificial modification and entry error of the test date, which seriously affect the quality and safety of the constructions.

2. System Design

The intelligent rebound system should have the functions of hammer displacement measuring, phonetic transcription, real-time data remote transmission, data storage and analysis, etc [12]. Among those elements, the phonetic transcription unit is required to complete the operator's voice recognition and transcription of location information, such as "101 East Wall Area 1" and "203 North Wall Area 4". The real-time data remote transmission unit is responsible for sending the hammer rebound value and phonetic transcription data to the cloud server in real time through the IoT module. The cloud information management unit is responsible for storing the data information transmitted by IoT and responding to the web request to render the data to the front-end page [13]. The schematic diagram of the system structure is shown in Figure 1.

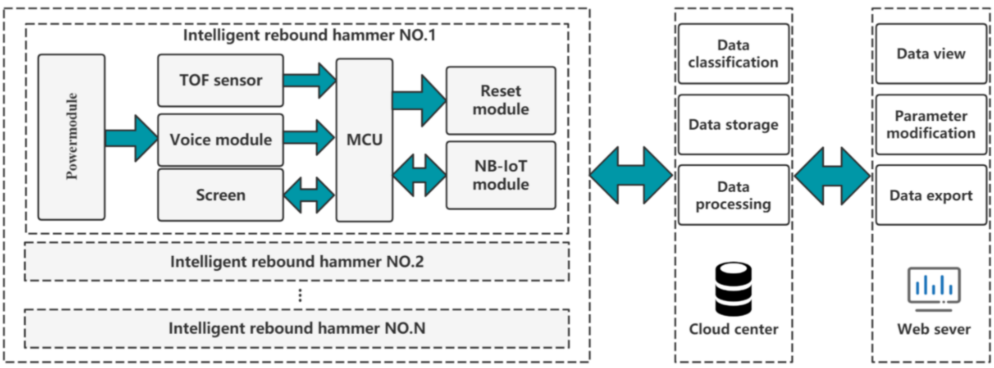


Figure 1. The schematic diagram of system structure.

2.1. Circuit Design

With consideration for the number of communication interfaces, the size of the hardware circuit board and the expansion space for subsequent system upgrading [14], the STM32F103C8T6 microcontroller is selected as the system MCU, which has up to 37 digital input/output ports, two 12-bit synchronized ADCs, two IICs, three UARTs, two SPIs, one CAN, three 16-bit timers, and 64 KB of program memory. The whole system is powered by a 5 V rechargeable lithium-ion battery pack with a capacity of 8400 mAh, which can work stably for longer than 8 h without interruption.

For non-contact range-finding, we chose a TOF050H module as the ranging sensor to measure the hammer rebound value, which works under 3.3 V and supports serial-mode, modbus-mode and IIC-mode data transfer [15]. In view of the range of rebound value [16], the high precision ranging mode is selected, the module range is 200 mm, accuracy is ±5%, resolution is 1 mm, and the ranging period is set to 200 ms.

For phonetic transcription, we chose a widely used LD3320 module to recognize and transcript the voice information of different locations, which has high-precision A/D and D/A interfaces and can achieve phonetic transcription without additional external auxiliary Flash and RAM [17]. During voice signal processing, the environment noise will firstly be removed from the recognized voice signal. The SPI clock, chip select and input and output pins are connected to the external MCU by SPI protocol to achieve serial interface communication. In view of the limited number of offline entries, the method of word combination is adopted to expand the recognition capability of LD3320, which uses the external MCU to sort and integrate recognized entries according to the time series.

In order to improve the recognition rate, an RC circuit is added to the microphone bias pin (MBS) to ensure a floating voltage is applied on the microphone. The schematic diagram of phonetic transcription unit is shown in in Figure 2.

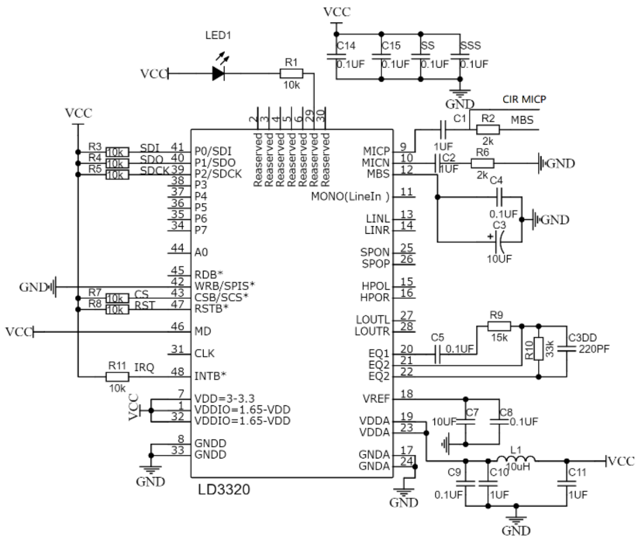
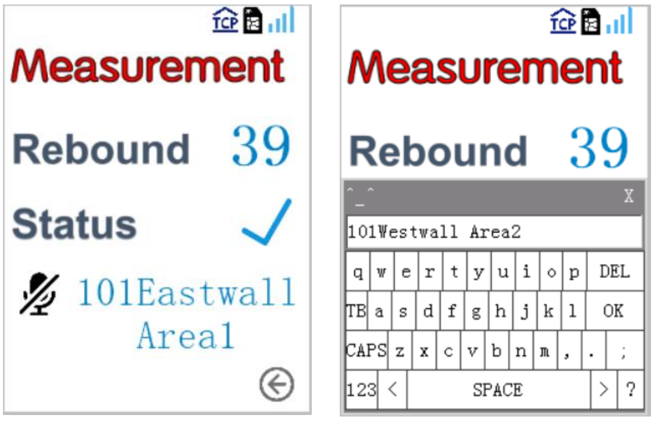


Figure 2. The schematic diagram of phonetic transcription unit.

For data remote transmission, we chose a Quectel BC26 communication module to send the hammer rebound value and phonetic transcription data to the cloud server in real time, which has low power consumption and high performance [18]. The BC26 module communicates with MCU through a UART serial port and builds a connection with the cloud server by TCP protocol [19].

In order to check the phonetic transcription results and the working status of the intelligent rebound hammer in real time, a 2.4-inch touchscreen display was selected as the user interface (TJC3224T124_011R, Taojingchi, Shenzhen, China); it works under 5 V and communicates with MCU through a serial port. The measured rebound value, recognized location information, communication signal strength and sending status are displayed on the display screen. If any errors in phonetic transcription are found, the operator can modify the speech text by the screen keyboard and send the revised text to the external MCU through serial port interrupt, as shown in Figure 3.



(**a**) (**b**)

Figure 3. (**a**) The user interface screen of intelligent rebound hammer. (**b**) The screen of user interface during modification of the recognized speech text.

2.2. Structure Design

In view of the ranging characteristics of the TOF050H module, the white reflector board is fixed on the slider, which can slide along the sliding rail. The nominal kinetic energy of the hammer is 2.207 J, and the measuring strength range of 10~60 MPa is related to the rebound displacement range of 20~60 mm. In view of the location and field angle of the ranging sensor, the width of the reflector board is set to 17 mm, which ensures the ranging sensor can cover the full field. The touchscreen is fixed on the top of the circuit box, and a 5.0 V rechargeable polymer lithium battery, which provides a power source for the rebound hammer, is fixed inside the circuit box. The schematic view of the intelligent rebound hammer is shown in Figure 4.

Figure 4. The schematic view of intelligent rebound hammer.

2.3. MCU Program Design

In order to distinguish the rebound value and phonetic transcription data from different intelligent rebound hammers, an 8-bit array is set to store the rebound value in which the front two bits are the data category, the middle four bits are the equipment number, and the last two bits are the rebound value. For example, if rebound hammer #1 is used to measure the concrete strength and the rebound value is 40 mm, the uploaded array will be "00000140". Furthermore, another 12-bit array is set to store the phonetic transcription data in which the front two bits are the data category, the middle four bits are the equipment number, and the last six bits are the phonetic transcription.

When the system is turned on, the system starts initializing, the BC26 module connects to the network. After network attaching, when the BC26 module closes the previous TCP connection and creates a new TCP connection, the system enters the main loop, which includes phonetic transcription, range-finding and data remote transmission. If the voice recognition button is held down, the system enters the process of voice recognition until the release of the button. The MCU sorts and integrates all recognized entries according to the time series, and the final result of phonetic transcription is sent to the cloud server as a 12-bit array. The MCU sends the rebound value and phonetic transcription to the server by calling the AT instruction and checks the returned value to judge the sending status. The program flow chart is shown in Figure 5.

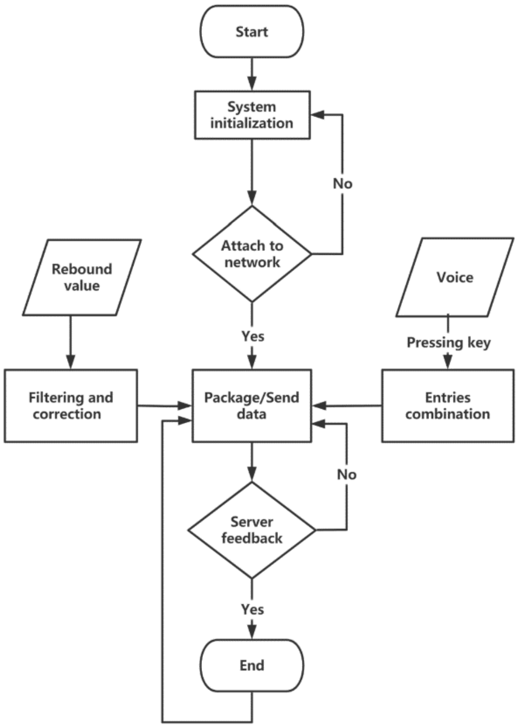


Figure 5. The program flow chart of the MCU.

2.4. Web Program Design

After establishing the connection with the server, the rebound hammer sends the collected data to a specified port. The server listens to the port via Python scripts, then analyzes, classifies and stores the received data into the Mysql database. The received 12-bit array will be translated into a text of location information according to the hash table, whereas the received 8-bit array of rebound values will be bound to the location according to the category and equipment number.

The front end of the cloud information management platform is developed by Vue.js, and the back end is developed by Python language. In view of the development cycle and extensibility, the web server is built with a Flask framework and interacts with the database via a PyMySQL module [20]. If the web server receives any requests from the front-end interface, it will render the response results to the browser. The workflow chart is shown in Figure 6.

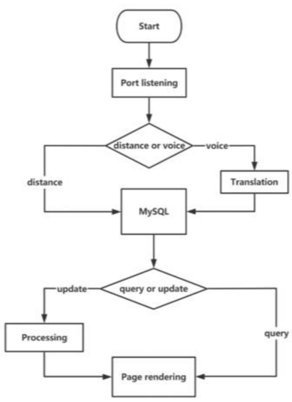


Figure 6. The workflow chart of the cloud information management platform.

As shown in Figure 7, on the webpage of the cloud information management platform, the manager can check the received test data, modify related parameters and export them to a text or excel file. After the parameter modification, such as the modification of impact angles, pouring surface and carbonization depth, the back end of the platform will modify the rebound value according to the technical regulations and convert the rebound value to the strength of the concrete automatically according to "Conversion Table of Compressive Strength of Concrete for Test Area".

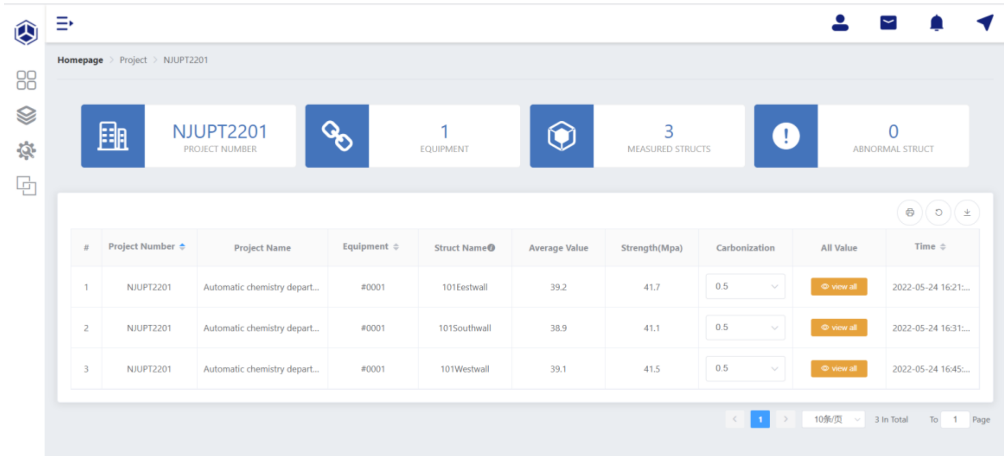


Figure 7. The webpage of the cloud information management platform.

3. Experimental Results

In order to check the performance of our home-made intelligent rebound hammer system, we chose one state grid substation construction in Nanjing to test the concrete strength. As shown in Figure 8, we chose four test areas on one load-bearing wall arbitrarily and divided them into 4 × 4 small grids, respectively. According to the JGJ/T 23-2011, before the test, the calibrated steel anvil of 60 ± 2 Rockwell hardness was used to calibrate the two rebound hammers, and the calibration results were within 80 ± 2. With the home-made intelligent rebound hammer, we tested the concrete strength for each small grid. The platform receives 16 rebound values for each test area, deletes 3 maxima and 3 minima, and finally calculates an average rebound value for each test area. In order to compare the performance, we chose another four close test areas in the same load-bearing wall and one commercial digital rebound hammer (YD225P, Daolong Technology Co., Ltd., Shenzhen, China). The test value of YD225P is deemed as the standard value, and the impact angle is set to 0. The test results of four test areas are shown in Table 1.

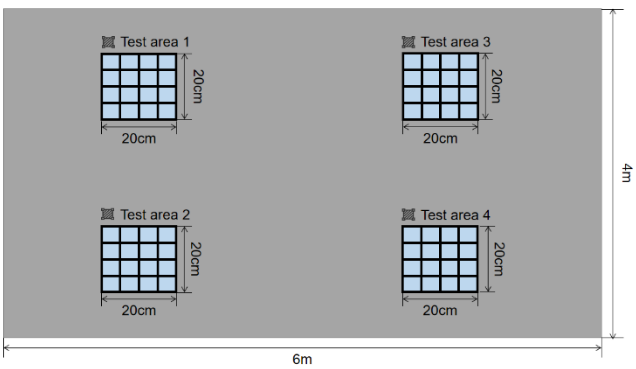


Figure 8. The schematic view of the measuring points for four test areas.

Table 1. Test Results of Four Test Areas.

Table 225.	YD225C					Home-Made					Relative Error
	Test Value				Mean Value	Test Value				Mean Value	
1	40 38 38 39	39 23 39 39	38 53 53 39	25 41 34 38	38.7	39 38 39 37	39 39 39 37	38 39 39 38	36 39 40 39	38.7	0%
2	24 40 39 39	39 40 39 40	39 40 42 40	40 39 38 39	39.4	41 40 40 40	39 39 39 26	39 24 54 42	40 40 54 35	39.7	0.70%
3	39 36 38 40	39 35 37 38	38 37 41 23	37 36 39 38	37.7	37 37 37 37	25 36 39 40	40 29 35 38	38 38 40 41	37.7	0%
4	27 26 41 44	38 39 39 46	26 39 38 42	39 40 40 38	39.1	40 38 37 39	38 38 40 39	39 38 33 39	39 39 37 38	38.5	1.50%

From Table 1, the relative error between two rebound hammer test results for four test areas is 0%, 0.70%, 0%, and 1.50%, respectively, which proves the good performance of our home-made intelligent rebound hammer system. After hundreds of tests and comparative analyses on different concrete structures in several engineering sites, we have confirmed the working performance and stability of our intelligent rebound hammer system. Most importantly, it can send the data of rebound value and location information to a remote cloud information management system without traditional multi-person collaboration, which avoids the risks of artificial modification or data transfer errors.

4. Conclusions

We have presented one novel intelligent rebound hammer based on IoT and speech recognition technology, which use a TOF050H laser ranging sensor to measure the hammer displacement and a LD3320 voice recognition module to record the location information. All the test data will be sent to a remote cloud information management system by the IoT module in real time, which can solve the problems of multi-person collaboration and burdensome data transfer and consequently avoid the risks of artificial modification and data transfer errors.

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References

1. McCann, D.M.; Forde, M.C. Review of NDT Methods in the Assessment of Concrete and Masonry Structures. *NDT E Int.* **2001**, *34*, 71–84. [CrossRef]
2. Agunwamba, J.; Adagba, T. A Comparative Analysis of the Rebound Hammer and Ultrasonic Pulse Velocity in Testing Concrete. *Niger. J. Technol.* **2012**, *31*, 31–39.
3. Kumavat, H.R.; Chandak, N.; Jadhav, D. Experimental Investigation on Relationships between Rebound Index and Compressive Strength of Cement Concrete Specimen Influenced by Physical Factors. In Proceedings of the 2020 Advances in Science and Engineering Technology International Conferences, ASET, Dubai, United Arab Emirates, 4–6 February 2020; pp. 1–5. [CrossRef]
4. Yuasa, N. Topic for Concrete Strength Presumption Using Rebound Hammer —Comparison between Rebound Numbers Using Various Hammers and Proposal of Requesting Method for Relationship between Rebound Numbers and Compressive Strength & mdash. *Concr. J.* **2010**, *48*, 23–30. [CrossRef]
5. Kumar, A.; Rattan, J.S.; Kapoor, N.R.; Kumar, A.; Kumar, R. Structural Health Monitoring of Existing Reinforced Cement Concrete Buildings and Bridge Using Nondestructive Evaluation with Repair Methodology. *Adv. Technol. Build. Constr. Struct. Anal.* **2021**, 87. [CrossRef]
6. Breysse, D.; Martínez-Fernández, J.L. Assessing Concrete Strength with Rebound Hammer: Review of Key Issues and Ideas for More Reliable Conclusions. *Mater. Struct.* **2014**, *47*, 1589–1604. [CrossRef]
7. Hu, S.; Yang, K.; Liu, Q. Portable Intelligent Rebound Hammer System. *J. Hefei Univ. Technol.* **2006**, *29*, 1273–1277. [CrossRef]
8. Chen, Y. Intelligent Rebound Hammer System Based on PSD and Zigbee. Master's Thesis, Hefei University of Technology, Hefei, China, 2007.
9. Bassoli, M.; Bianchi, V.; De Munari, I.; Ciampolini, P. An IoT Approach for an AAL Wi-Fi-Based Monitoring System. *IEEE Trans. Instrum. Meas.* **2017**, *66*, 3200–3209. [CrossRef]
10. Ali, S.; Glass, T.; Parr, B.; Potgieter, J.; Alam, F. Low Cost Sensor With IoT LoRaWAN Connectivity and Machine Learning-Based Calibration for Air Pollution Monitoring. *IEEE Trans. Instrum. Meas.* **2021**, *70*, 1–11. [CrossRef]
11. Ferrari, P.; Sisinni, E.; Bellagente, P.; Carvalho, D.F.; Depari, A.; Flammini, A.; Pasetti, M.; Rinaldi, S.; Silva, I. On the Use of LoRaWAN and Cloud Platforms for Diversification of Mobility-as-a-Service Infrastructure in Smart City Scenarios. *IEEE Trans. Instrum. Meas.* **2022**, *71*, 1–9. [CrossRef]
12. Gutiérrez, J.; Villa-Medina, J.F.; Nieto-Garibay, A.; Porta-Gándara, M.Á. Automated Irrigation System Using a Wireless Sensor Network and GPRS Module. *IEEE Trans. Instrum. Meas.* **2014**, *63*, 166–176. [CrossRef]
13. Zhang, H.; Li, J.; Wen, B.; Xun, Y.; Liu, J. Connecting Intelligent Things in Smart Hospitals Using NB-IoT. *IEEE Internet Things J.* **2018**, *5*, 1550–1560. [CrossRef]
14. Reverter, F. Toward Non-CPU Activity in Low-Power MCU-Based Measurement Systems. *IEEE Trans. Instrum. Meas.* **2020**, *69*, 15–17. [CrossRef]
15. Lin, J.-T.; Newquist, C.A.; Harnett, C.K. Multitouch Pressure Sensing With Soft Optical Time-of-Flight Sensors. *IEEE Trans. Instrum. Meas.* **2022**, *71*, 1–8. [CrossRef]
16. *JGJ/T 23-2011*; Ministry of Housing and UrbanRural Development of the People's Republic of China Technical Specification for Inspecting of Concrete Compressive Strength by Rebound Method. Ministry of Housing and UrbanRural Development of the People's Republic of China: Beijing, China, 2011.
17. Price, M.; Glass, J.; Chandrakasan, A.P. A Low-Power Speech Recognizer and Voice Activity Detector Using Deep Neural Networks. *IEEE J. Solid-State Circuits* **2018**, *53*, 66–75. [CrossRef]
18. Popli, S.; Jha, R.K.; Jain, S. A Survey on Energy Efficient Narrowband Internet of Things (NBIoT): Architecture, Application and Challenges. *IEEE Access* **2019**, *7*, 16739–16776. [CrossRef]
19. Gomez, C.; Arcia-Moret, A.; Crowcroft, J. TCP in the Internet of Things: From Ostracism to Prominence. *IEEE Internet Comput.* **2018**, *22*, 29–41. [CrossRef]
20. Trianti, C.A.; Kristianto, B. Hendry Integration of Flask and Python on The Face Recognition Based Attendance System. In Proceedings of the 2021 2nd International Conference on Innovative and Creative Information Technology (ICITech), Salatiga, Indonesia, 23–25 September 2021; pp. 164–168. [CrossRef]

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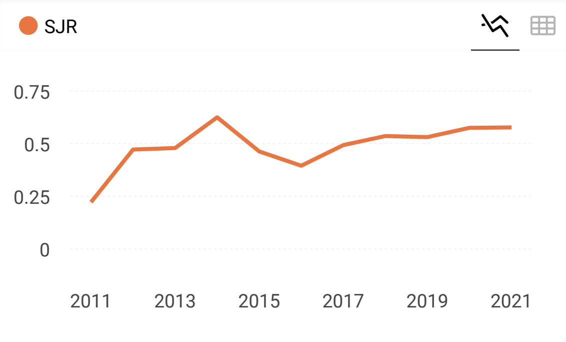

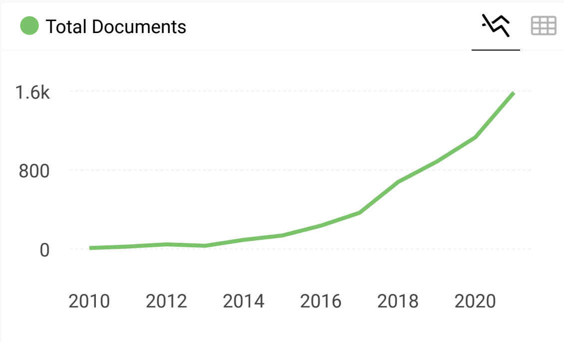

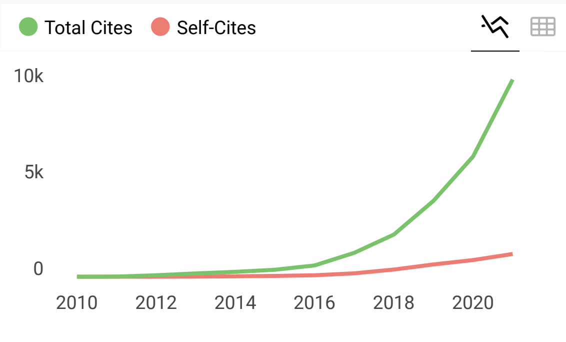

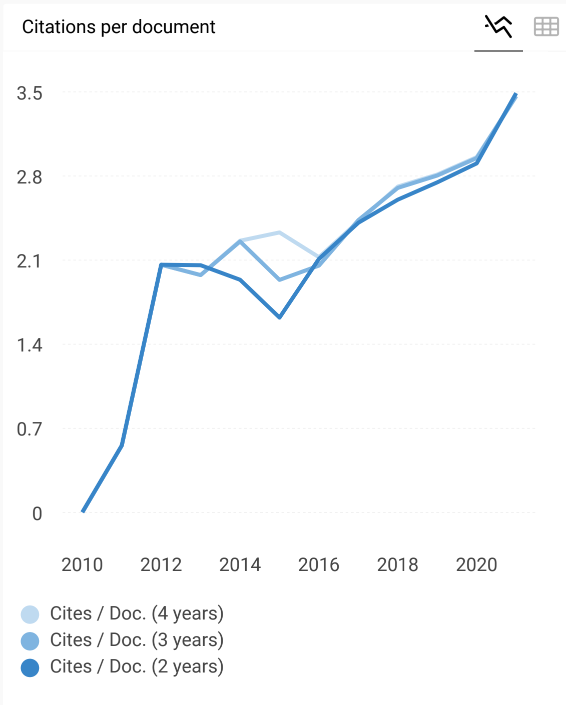

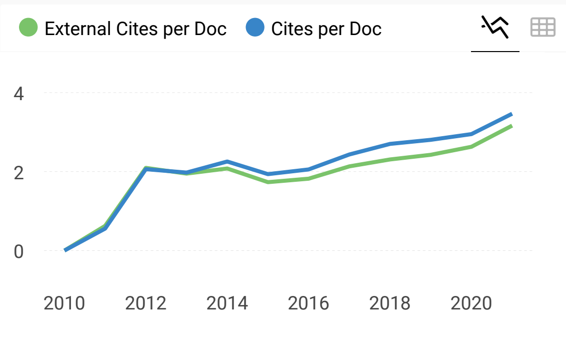

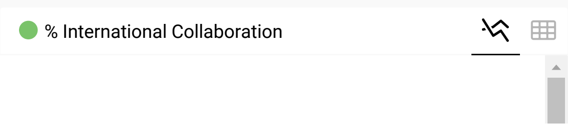

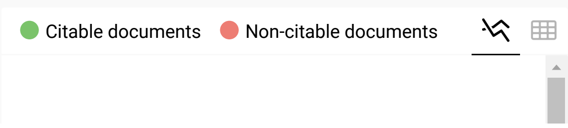

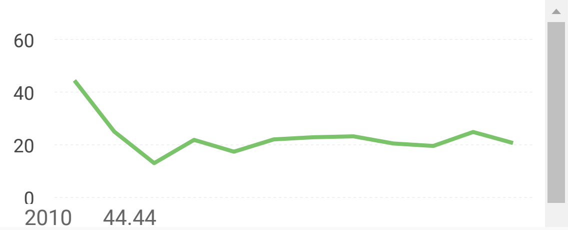

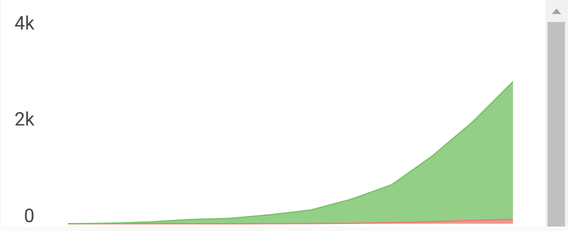

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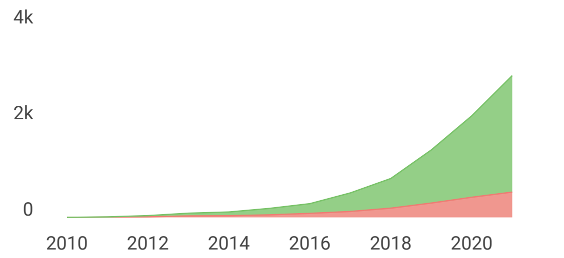

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Abstract:
Over the last few decades, the interest in using advanced high performance materials in the construction industry has been shooting up and developing. Recently, very high strength cement based composite with high ductility called Reactive Powder Concrete (RPC) has been developed. The RPC concept is based on the principle that a material with a minimum of defects such as micro-cracks and voids will be able to achieve a greater load – carrying capacity and greater durability. In the present paper, an experimental program of sixteen reinforced concrete one way slabs was conducted to investigate their behavior under flexural loading. Four of these slab with normal concrete (NC) and the others of Modified Reactive Powder Concrete (MRPC). All slabs identical in dimension of its length and width (1000×500) mm, respectively, and its thickness was varied as one of the variable which used in the present work. Also, other parameters one way slab, reactive were varied; concrete type, steel fibers content and flexural steel reinforcement ratio. The results showed the MRPC slabs with steel fibers were failed in ductile manner and had ultimate load capacity more than of that non-fibrous MRPC with improvement percentage reach to (66) %, while this percentage was became (212) %, comparisons with normal concrete slabs. Also, the results showed that slabs, for both concrete types, reinforced with lower steel ratio failed by tension mode, otherwise, the slabs of higher reinforcement steel ratio

flailed by combined tension-shear mode. However, an improvement was gained in the ultimate load capacity up to (53 and 98) % when increased the ratio of steel reinforcement and slab thickness, respectively.

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RESEARCH ARTICLE

Flexural Strength of Modified Reactive Powder Concrete One Way Slabs

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Abstract:

Background:

Over the last three decades, the interest in using advanced high-performance materials in the construction industry has been increasing worldwide. Recently, a very high strength cement-based composite with high ductility called Reactive Powder Concrete (RPC) has been developed. The RPC concept is based on the principle that a material with a minimum of defects such as micro-cracks and voids will be able to achieve greater load-carrying capacity and durability.

Methods:

In the present paper, an experimental program of sixteen reinforced concrete one-way slabs was conducted to investigate their behavior under flexural loading. Four of these slabs were with Normal Concrete (NC) and the others of Modified Reactive Powder Concrete (MRPC). All slabs were identical in the dimension of its length and width (1000×500) mm, respectively, and its thickness was varied as one of the variables used in the present work. Other parameters for a one-way slab are concrete type, steel fibers content and flexural steel reinforcement ratio (0.33 and 0.66)%.

Results:

The results showed that the MRPC slabs with steel fibers failed in a ductile manner and had ultimate load capacity more than that of non-fibrous MRPC with an improvement percentage that reaches up to (66) %. This percentage became (212) % in comparison with normal concrete slabs.

Conclusions:

Moreover, the results showed that slabs, for both concrete types, reinforced with lower steel ratio failed by tension mode, otherwise, the slabs of higher reinforcement steel ratio failed by combined tension-shear mode. However, an improvement was observed in the ultimate load capacity up to (53 and 98) % when the ratio of steel reinforcement and slab thickness increased, respectively.

Keywords: Powder concrete, Structural behavior, Steel fiber, Way slabs, Concretes, Quartz sand.

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1. INTRODUCTION

Reinforced concrete is a construction material that is most commonly used in developing countries. The ease with which reinforced concrete is used for construction is due to generally well-established properties, which are some of the reasons for its popular choice. There is a need to ensure detailed information on the strength and deformational properties of reinforced concrete to technical specifications of the required code of practice, particularly when a new constituent material is substituted in it.

Recently, a very high strength cement-based composite with high ductility called Reactive Powder Concrete (RPC) has been developed in Bouygues, France [1]. Reactive Powder Concrete provides many enhancements in properties compared to conventional and high strength concrete of all particles in the mix to yield maximum density. The term Reactive Powder Concrete (RPC) has been used to describe a fiber-reinforced, super plasticized, silica fume-cement mixture with a very low water-cement ratio (w/c) characterized by the presence of very fine Quartz sand (0.15-0.40 mm) instead of ordinary aggregate. In fact, it is not concrete because there is no coarse aggregate in the cement mixture. The absence of coarse aggregate was considered by the inventors to be a key aspect for the microstructure and the performance of the RPC in order to reduce the heterogeneity between the cement matrix and the aggregate. RPC represents a new class of Portland cement-

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based material with compressive strength's in excess of 200MPa. By introducing fine steel fibers, RPC can achieve remarkable flexural strength up to 50MPa. The material exhibits high ductility with typical values for energy absorption approaching those reserved for metals.

Many researches over the past decades have developed and investigated this type of concrete (RPC), now labeled and classified as Ultra High Strength Concrete (UHSC), which is one of the latest advances in concrete technology and it addresses the shortcoming of many concrete today [2 - 4]. Another search was conducted to modify RPC by replacing a fraction of quartz sand by graded natural aggregate (max size 8 mm) and to study the influence of the graded aggregate on the properties of cement mixtures in terms of required water-cement ratio, compressive and flexural strength. Though RPC is economical as compared to steel structures by itself and is replacement in such cases, it can be made still economical and feasible by modifying it by replacing Quartz powder by natural graded aggregate [5 - 8].

The first production of MRPC belonged to Collepardi *et al* [5] when they published their first paper in 1997.

According to this paper, MRPC can be produced by the following four ways:

[1] Replacing part of fine sand by 8 mm crushed aggregate.
[2] Replacing all fine sand by 8 mm crushed aggregate.
[3] Replacing part of the cementitious binder (cement + silica fume) by 8 mm crushed aggregate.
[4] Replacing all fine sand and part of the cementitious materials by 8 mm crushed aggregate.

Results showed that the compressive strength of MRPC was 155 MPa (at 28 days) by using normal curing at 20°C , 160 MPa (at 7 days) by using heat curing at 90°C and more than 200 MPa (at 3 days) by using a heat curing at 160°C. Flexural strength was 35.5 MPa (at 28 days and T=20°C), 38.9 MPa (at 7 days and T =90°C) and 40.1 MPa (at 3 days and T =160°C).

The fiber reinforcement can extend the technical benefits of MRPC by also providing crack bridging ability, higher toughness and long-term durability.

2. ADVANTAGES AND APPLICATIONS OF RPC

The reactive powder concrete has many advantages, summarized as follow [1]:

- Better alternative to HPC.
- High Tension Ductile failure mechanism eliminates the need for reinforcing steel.
- Improved seismic performance by reducing inertia loads with lighter members.
- Low and non-inter connected porosity diminishes mass transfer.
- The main advantage that RPC has over standard concrete is its high compressive strength.
- RPC construction requires low maintenance costs in its service life.

Also, this type of concrete can be used in many types of structural elements [1]:

- RPC has found application in the storage of nuclear waste, bridges, roofs, piers, seismic-resistant structures and structures designed to resist Impact/blast loading.
- Owing to its high compression resistance, precast structural elements can be fabricated in the slender form to enhance aesthetics.
- Durability issues of traditional concrete have been acknowledged for many years and significant funds have been necessary to repair aging infrastructure.
- Reactive Powder Concrete possesses good durability properties.
- RPC usually incorporates larger quantities of steel or synthetic fibers and has enhanced ductility and high-temperature performance.

3. LITERATURE REVIEW

One-way slabs transfer the imposed loads in one direction only. They may be supported on two opposite sides only, in which the structural action is essentially one-way, the loads being carried in a direction perpendicular to the supporting beams or walls. Several research projects have been carried out to investigate the behavior of one-way reinforced concrete slabs. Some of these have characterized conventional concrete and steel reinforcement characteristics, whilst others have also characterized non-ferrous reinforcement bars for use in concrete. The effect of concrete type by using normal, self-compacted, and lightweight concrete was investigated by many researchers [9, 10] on the flexural and shear characteristics of one-way slabs. The effect of reinforcement type, conventional, steel bars milled from scrap metals and modern reinforcement (GFRP), was conducted to show the flexural behavior of one-way concrete slabs subjected to monotonic and variable-amplitude repeated loading [11 - 21]. However, some of the researches deal with the effect of lacing reinforcement on the shear strength of the performance of one way concrete slabs in the large-deflection region.

Therefore, from the previous work, it can be noted, that little or no investigations have been carried out on the flexural behavior of one way concrete slabs cast with steel fiber reinforced Modified Reactive Powder Concrete (MRPC). Conventional Reinforced Concrete (RC) is known to have limited ductility and concrete confinement capabilities. The structural properties of RC can be improved by modifying the concrete matrix and by suitably detailing the reinforcements. Therefore, the present study deals mainly with the behavior of (MRPC) one-way slabs reinforced internally with steel reinforcements under constant loading conditions, where the physical and mechanical properties of MRPC are very different from that conventional concrete. Such differences arise both from materials properties and interaction mechanisms between the MRPC reinforcement and the concrete [7, 8].

4. OBJECTIVE AND SCOPE

Strength and deflection prediction for steel-reinforced concrete elements are dependent on empirical performance constants. The empirical components reflect the material-specific composite behavior of steel and concrete. The objective of this study is to investigate the flexural strength and deflection behavior of one way reinforced slab casted by MRPC. The research describes the various limit state behavior including modes of failure due to variation of the slab thickness, the steel fiber content and the reinforcement ratio. The behavior of concrete slabs made by MRPC is compared to slabs casted by normal concrete NC. This study clearly shows that the behavior of MRPC slabs is different from that casted by using conventional concrete. This paper should also provide engineers and researchers with a better understanding of the performance of these new composite materials in concrete structures. The information gathered throughout this investigation is valuable for the future development of design guidelines for one-way MRPC slabs.

5. MATERIALS AND METHODS

5.1. Experimental Methodology

In the present study, an experimental program will be prepared to provide a much needed understanding of the behavior of MRPC one-way slabs under line loading. The experimental program was conducted a series of reinforced one-way slabs of normal and modified reactive powder concrete which were casted to illustrate the effect of concrete type, steel fiber content, slab thickness and flexural reinforcement ratio. Initially, the mechanical description of constitute materials was given. As well as the mechanical properties of normal and modified reactive powder concrete were investigated by using control specimens were casted which were three cylinders for compressive strength, three cylinders for splitting tensile strength and three prisms for modulus of rupture.

Four variables were investigated in this study to show their effects on the flexural strength of the NC and MRPC slabs. These variables are:

[1] Percentage of steel fibers volumetric ratio (0, 0.4, and 0.8) %.

[2] Flexural steel reinforcement ratio (ρ_1=0.0033 and ρ_2=0.0066).

[3] Thickness of slab (T=50 and T=70) mm.

[4] Type of concrete [Normal Concrete (NC) and Modified Reactive Powder Concrete (MRPC)].

Table **1** illustrates the details of all the test slabs.

Slabs designations were as following:

NCS is Normal Concrete Slab,

MRPCS is Modified Reactive Powder Concrete Slab,

the symbol (1 and 2) from (ρ_1=0.0033 or ρ_2=0.0066),

the symbol (0, 0.4 and 0.8) from steel fibers content (V_f=0, 0.4 or 0.8%),

and the symbol (50 and 70) from slab thickness (T=50 or T=70) mm.

5.2. Material Characteristics

Ordinary Portland cement (Type I) produced in Iraq (TASLUJA-BAZIAN) was used in this study. The chemical and physical properties indicated that the adopted cement conforms to the specification.

Al-Ekhaider natural sand of 4.75mm maximum size was used as fine aggregate in normal concrete. However, for RPC, very fine sand with a maximum size of 600μm was used. Crushed gravel from the AL-Nibaey region was used for MRPC and reference concrete specimens with a maximum size of (8 and 10mm), respectively. Results indicate the grading of these materials (aggregates) within the requirements of the specification.

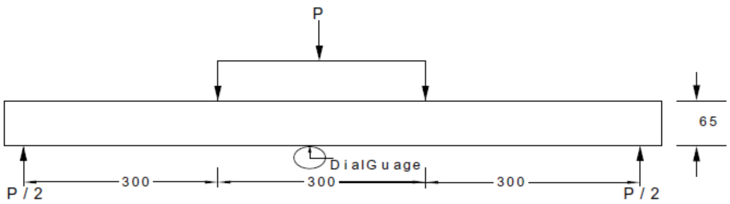
Table 1. Details of tested slabs.

Group No.	Slab Designation	Steel Reinforcement Ratio (ρ)	Steel Fibers % by Volume	Slab Thickness (mm)
Group One (normal concrete slabs as references) (NC)	NCS1-0-50	0.0033	0	50
	NCS1-0-70	0.0033	0	70
	NCS2-0-50	0.0066	0	50
	NCS2-0-70	0.0066	0	70
Group Two (MRPC0)	MRPCS1-0-50	0.0033	0	50
	MRPCS1-0-70	0.0033	0	70
	MRPCS2-0-50	0.0066	0	50
	MRPCS2-0-70	0.0066	0	70
Group Three (MRPC-0.4)	MRPCS1-0.4-50	0.0033	0.4	50
	MRPCS1-0.4-70	0.0033	0.4	70
	MRPCS2-0.4-50	0.0066	0.4	50
	MRPCS2-0.4-70	0.0066	0.4	70
Group Four (MRPC-0.8)	MRPCS1-0.8-50	0.0033	0.8	50
	MRPCS1-0.8-70	0.0033	0.8	70
	MRPCS2-0.8-50	0.0066	0.8	50
	MRPCS2-0.8-70	0.0066	0.8	70

Table 2. Properties of the different types of (MRPC and NC) mixes.

Mix Type	Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3	Silca Fume* %	Silica Fume kg/m^3	w/c	Viscocrete PC20* %	Steel Fiber Content** %	Steel Fiber Content kg/m^3
MRPC0	900	495	495	25	225	0.18	5	0	0
MRPC0.4	900	495	495	25	225	0.18	5	0.4	31.4
MRPC0.8	900	495	495	25	225	0.18	5	0.8	62.8
NC	400	600	1200	0	0	0.5	0	0	0

*Percent of cement weight. **Percent of mix volume.



A- All dimensions in mm

B

Fig. (1). A-Schematic sketch of typical experimental set-up. **B**-Specimen and loading instrumentation.

To improve the workability and strength of concrete, high range water reducing admixture used in this study is known commercially as Viscocrete-PC20. This type of superplasticizer is imported from Sika Company. In the present investigation, silica fume was used, which imported from Sika Company. Tap water was used in all mixes and the curing of the specimens.

Micro straight steel fibers with a diameter of 0.25 mm, length of 13.1mm, aspect ratio (L/d) of 52 and yield strength of 1130 MPa were used in MRPC mixes.

Deformed steel bar of nominal diameter (6) mm was used as slab reinforcement. Two reinforcement ratios (ρ) were used in each group of the tested slabs. The yield strength of the used bar was 435 MPa. The result of testing this bar meets the ASTM A615 requirements for Grade 60 steel.

5.3. Mixes and Mixing Procedure

Three types of modified reactive powder concrete MRPC mixes were used in the present research, as listed in Table **2**. The variables adopted in these mixes were the volume ratio of steel fibers (three-volume ratios were considered 0, 0.4 and 0.8) %. The mixed type of normal concrete NC was adopted as a reference mix, (Table **2**).

In the present work, mixing was performed by using a 0.19 m^3 capacity horizontal rotary mixer. Firstly, the silica fume powder was mixed in a dry state with the required quantity of sand for 5 minutes. Then, cement and crushed gravel were loaded into the mixer and mixed for another 5 minutes. The required amount of tap water was mixed with superplasticizers and then added to the rotary mixer within 5 minutes. Finally, when steel fibers were used, they were introduced, and dispersed uniformly and mixed for an additional 2 minutes. This procedure is similar to the method used by Wille *et al* [2, 8] which was used successfully to produce RPC with compressive strength exceeding 150MPa without using heat curing; this is a major factor in the process of production.

5.4. Details and Designation of Slabs

Sixteen slabs of dimensions (1000×450×50 or 70) mm were cast and tested in flexure in this study. Four of these slabs were made with NC and twelve with MRPC. The slabs were simply supported at their ends with a clear span of (900) mm. The central deflection of the slabs had been measured by means of (0.01mm/div.) sensitivity dial gauge of (30)mm capacity placed at their center of the tension face. Two-line loads were applied at the third points of the slab by means of a hydraulic jack (Fig. **1**). The test procedure included crack monitoring and central deflection measurements for load increments of 5 kN.

6. RESULTS AND DISCUSSION

6.1. Hardened mrpc Mechanical Properties Results

Table **3** shows the test results of mechanical properties obtained for the four mixes. These properties are concrete compressive strength (f'_c), splitting tensile strength (f_t) and modulus of rupture (f_r). Each value presented in this table represents the average value of the three specimens.

The effect of steel fibers on concrete compressive strength seems to be small for MRPC and about (20) % as compared with control specimens without steel fibers. However, the splitting tensile strength and modulus of rupture are more affected by using steel fibers and about (50) % compared with control specimens without steel fibers.

6.2. Test Results of One-Way Slabs

Table **4** summarizes the results of the first cracking load (P_{cr}), ultimate load (P_u) and mode of failure for all tested slabs together with their deflection.

6.3. Deflections

The load- central deflection relationships for the tested slabs are shown in Figs. (**2**-**4**). From this relation, it can be observed that at initial loading, the relationship is approximately linear elastic characteristics with no crack occurrence. However, when the cracking load (Pcr) was exceeded and the first crack developed at the bottom of the slab within the middle third where maximum bending occurred, the gradient of the initial load-central deflection curve was reduced and continued to reduce gradually until the steel yielded. At the post-yield stage of the slab's reinforcement, where strain hardening occurred, such that a slight increase in the subjected load was lead a large increase in the central deflection until the slab failure was occurred.

Table 3. Tests results of mechanical properties for hardened NC and MRPC.

f_r (MPa)	f_t (MPa)	f'_c (MPa)	Mix Name
4.41	3.12	33	NC
8.1	6.4	84	MRPC
10.2	7.3	93	MRPC-0.4
12	9.1	100	MRPC-0.8

Table 4. Tests results of one-way slabs specimens.

Slab Designation	Compressive strength (f'_c) (MPa)	P_{cr} (kN)	P_u (kN)	P_{cr}/ P_u	Δ_u (mm)	Mode of Failure
NCS1-0-50	33	9	29	0.31	2.38	T.F.
NCS1-0-70		12	41	0.29	3.79	T.F.
NCS2-0-50		12	42	0.28	2.93	S.F
NCS2-0-70		15	56	0.28	6.5	T.F.+S.F.
MRPCS1-0-50	84	21	73	0.29	4.65	T.F.
MRPCS 1-0-70		35	128	0.27	6.67	T.F.
MRPCS 2-0-50		30	97	0.31	7.1	T.F.+ S.F.
MRPCS 2-0-70		39	146	0.27	7.6	T.F.+ S.F.
MRPCS 1-0.4-50	93	26	106	0.25	7.14	T.F.
MRPCS 1-0.4-70		43	189	0.23	17.5	T.F.
MRPCS 2-0.4-50		33	112	0.29	7.4	T.F.+ S.F.
MRPCS 2-0.4-70		43	152	0.28	12.1	S.F.
MRPCS 1-0.8-50	100	32	119	0.27	5.75	T.F.
MRPCS 1-0.8-70		43	158	0.27	12.65	T.F.
MRPCS 2-0.8-50		36	122	0.29	7.0	T.F.+ S.F.
MRPCS 2-0.8-70		58	242	0.24	19.96	T.F.

- T.F.: Tension Failure.
- S.F.: Shear Failure.

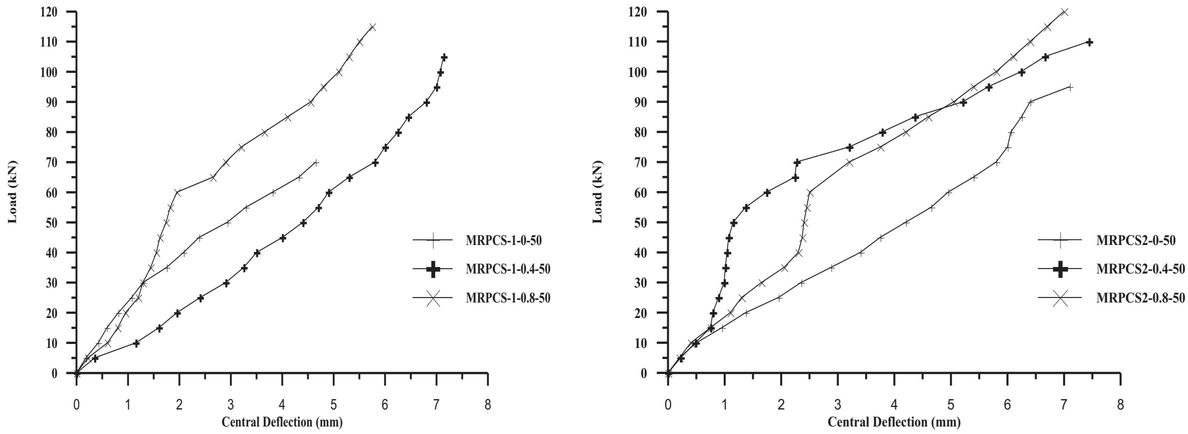


Fig. (2). Load-deflection curve of slabs with variable steel fiber.

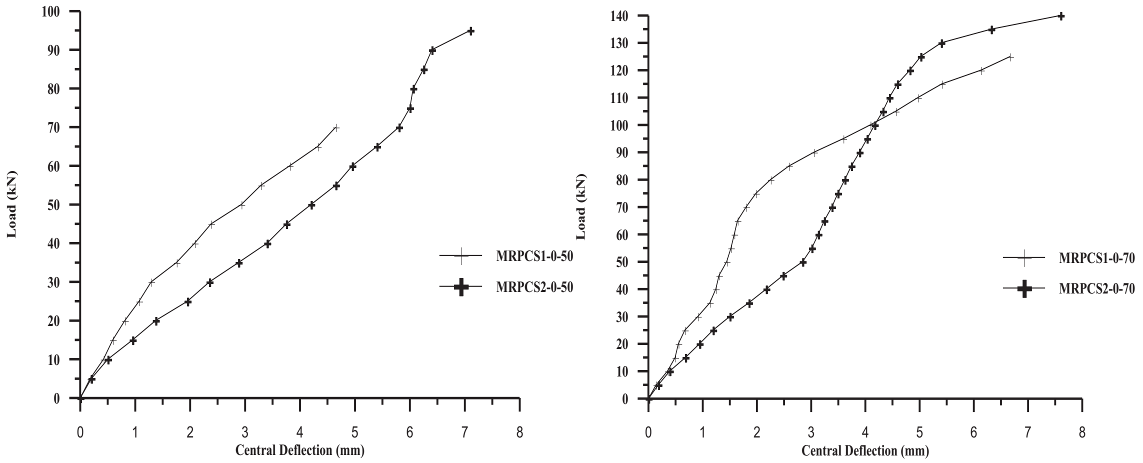


Fig. (3). Load-deflection curve of slabs with variable steel reinforcement.

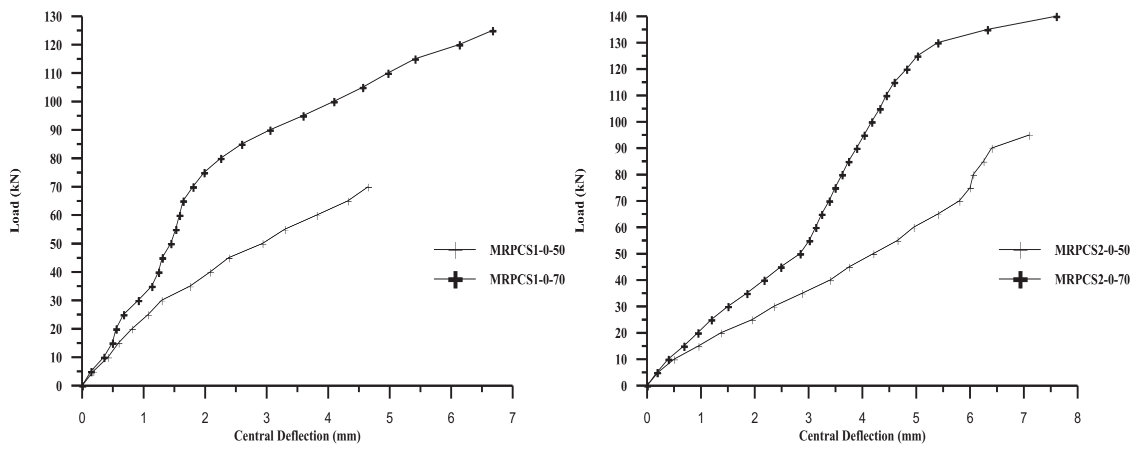


Fig. (4). Load-deflection curve of slabs with variable thickness.

6.4. First Cracking and Ultimate Failure Load

Generally, at a low level of load, concrete resists the stresses at the tension face of the slab and it's free from any cracks. When the load level was increased, the extreme fiber concrete stress reaches its limiting concrete tensile stress and hair-fine flexure cracks occurred. The load at this stage is called the first cracking load. As the load was increased above this stage of loading, the cracks seem to be widened and start to propagate, then, generally, extend (to be initiated) and deviate towards the slab free sides up to failure.

The first crack was observed visually and the recorded loads at this stage for all the tested slabs were to be at (23 to 31) % of the slab failure load. In general, the first cracking load for all the tested slabs appeared under the loading point. The cracking load and ultimate load for all tested slabs are listed in Table **4**.

6.5. Modes of Failure

For a simply supported one-way slab subjected to equal transverse loads at the third point, the middle third of the span is subjected to pure bending (such that it is under zero shear and maximum bending moment); whilst the remaining sections experience maximum shear force and varying bending moment. The middle third experienced the largest strains and therefore, concrete beneath undergoes cracking first. However, many of the slabs were failed by flexural tension mode and the others by combined modes of flexural tension and flexural shear. One of these slabs was failed by shear mode. Each of the slabs developed at least one shear crack. The shear cracks developed after several flexural cracks had developed. Typical crack configurations have been illustrated in Fig. (**5**).

6.6. Effect of Concrete Type

Effect of concrete type (NC and MRPC) and the compressive strength of their concrete (f'c) on cracking and ultimate loads and the increasing ratio between them for all tested slabs are detailed in Table **5**. The improvement in the first cracking and ultimate loads due to increasing the (f'c) value, for modified reactive powder concrete, reached to (190 and 212) %, respectively. However, increasing (f'_c) value, approximately, reduced the deflection for all load stages. The increase in (f'_c) value results in higher modulus of elasticity, which ultimately results in higher flexural rigidity (EI); therefore, the deflection is smaller.

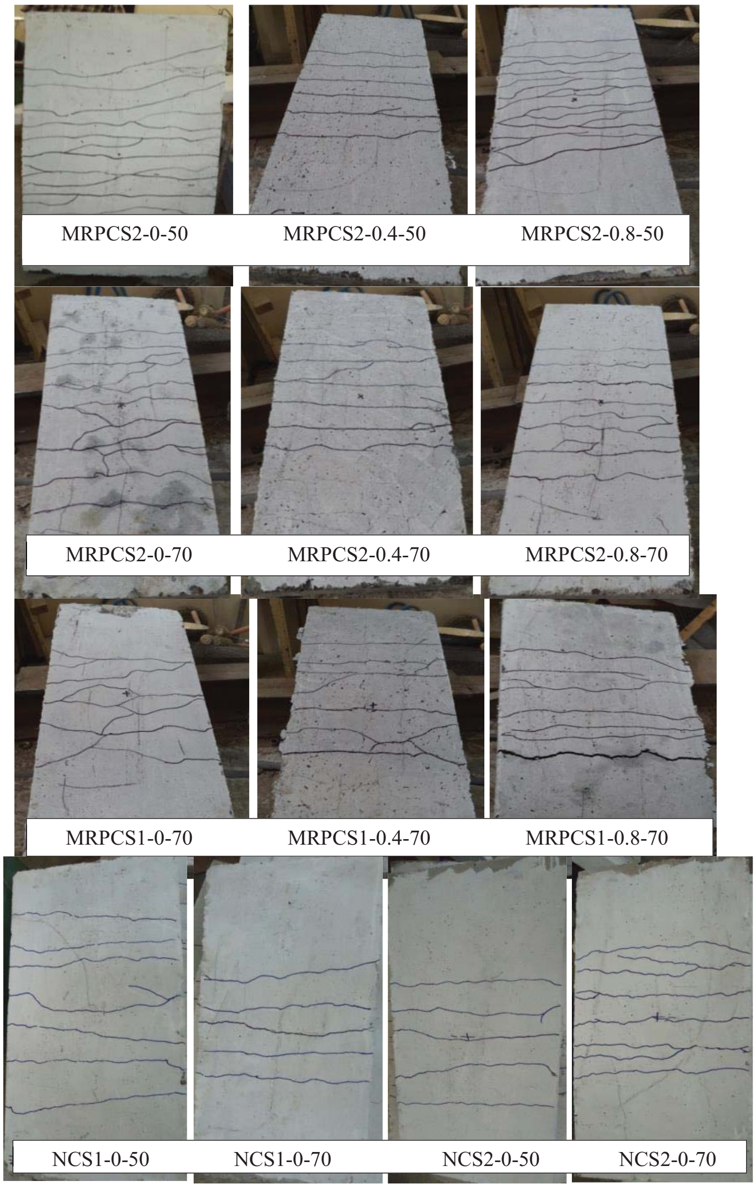


Fig. (5). Crack pattern of tested slabs.

Table 5. Effect of (f′c) on cracking and ultimate loads.

Slab Designation	f′c (MPa)	P_{cr} (kN)	P_u (kN)	P_{cr}/P_u	ΔP_{cr} %	ΔP_u %
NCS1-0-50	33	9	29	0.43	130	151
MRPCS1-0-50	84	21	73	0.42		
NCS1-0-70	33	12	41	0.36	190	212
MRPCS1-0-70	84	35	128	0.46		
NCS2-0-50	33	12	42	0.26	150	130
MRPCS2-0-50	84	30	97	0.44		
NCS2-0-70	33	15	56	0.22	160	160
MRPCS2-0-70	84	39	146	0.48		

Table 6. Effect of using 0.4% steel fibers on cracking and ultimate loads.

Slab Designation	V_f%	P_{cr} (kN)	P_u (kN)	P_{cr}/P_u	ΔP_{cr} %	ΔP_u %
MRPCS1-0-50	0	21	73	0.29	24	45
MRPCS1-0.4-50	0.4	26	106	0.25		
MRPCS1-0-70	0	35	128	0.27	23	47
MRPCS1-0.4-70	0.4	43	189	0.23		
MRPCS2-0-50	0	30	97	0.31	11	16
MRPCS2-0.4-50	0.4	33	112	0.29		
MRPCS2-0-70	0	39	146	0.27	8	5
MRPCS2-0.4-70	0.4	42	152	0.28		

Table 7. Effect of using 0.8% steel fibers on cracking and ultimate loads.

Slab Designation	V_f%	P_{cr} (kN)	P_u (kN)	P_{cr}/P_u	ΔP_{cr} %	ΔP_u %
MRPCS 1-0-50	0	21	73	0.29	50	63
MRPCS 1-0.8-50	0.8	32	119	0.27		
MRPCS1-0-70	0	35	128	0.27	23	23
MRPCS1-0.8-70	0.8	43	158	0.27		
MRPCS2-0-50	0	30	97	0.31	20	26
MRPCS2-0.8-50	0.8	36	122	0.29		
MRPCS2-0-70	0	39	146	0.27	48	66
MRPCS2-0.8-70	0.8	58	242	0.24		

6.7. Effect of Volumetric Steel Fiber Ratio (V_f)

Effect of volumetric steel fiber ratio (V_f) on cracking and ultimate loads and the ratio of them for all tested slabs are listed in the Tables **6**, **7** and **8** for V_f= 0.4% and 0.8%, respectively. Comparison with MRPC slabs without steel fibers, the improvement in the ultimate load value of slabs inclusion (V_f) 0.4% and 0.8% was reached up to (47 and 66) %, respectively. This means that this percentage of improvement of the ultimate load was increased as increased the content of steel fibers in the MRPC slabs.

Therefore, it can be observed from these tables that the improvement in cracking a load of slabs due to inclusion (V_f) percentages of 0.4% and 0.8%, comparison with MRPC slabs without steel fibers, was reached up to (24 and 50) %, respectively. It is clear that the improvement became higher as the steel fiber content increased.

The presence of steel fibers results in a delay in crack initiation and propagation where they hold concrete particles and prevent them from initial separation. Therefore, the first crack in fibrous concrete slabs appears at a load level appreciably higher than the load, which causes crack initiation in non-fibrous concrete slabs. After cracking, the steel fibers prevent the crack widening and delay its growth by the absorption of a portion of tension stresses carried by concrete *i.e.*, this action reduces the tension stresses applied to the concrete. Therefore, the failure takes place in fibrous concrete slabs at a load level higher than that of non-fibrous concrete slabs. Moreover, this is observed from that the effect of including the steel fibers on the enhancement of the mechanical properties (compressive strength (f'_c), splitting tensile strength (f_t) and modulus of rupture (f_r)) of MRPC as present in Table **2**.

However, it can be seen from the Table **4** that when increasing the steel fiber content in the MRPC slab up to 0.8%, slab of MRPCS2-0.8-70, the mode of failure was changed from shear to tension. This may be due to the effects of steel fiber, which delay the propagation of a crack in the shear zone, thereby, transform the failure to flexural mode.

Table 8. Effect of flexural steel reinforcement ratio on the ultimate failure load.

Slab Designation	ρ	P_{cr} (kN)	P_u (kN)	P_{cr}/P_u	ΔP_{cr} %	ΔP_u %
NCS1-0-50	0.0033	9	29	0.31	33	45
NCS2-0-50	0.0066	12	42	0.28		
NCS1-0-70	0.0033	12	41	0.29	25	37
NCS2-0-70	0.0066	15	56	0.28		
MRPCS1-0-50	0.0033	21	73	0.29	43	33
MRPCS2-0-50	0.0066	30	97	0.31		
MRPCS1-0-70	0.0033	35	128	0.27	12	14
MRPCS2-0-70	0.0066	39	146	0.27		
MRPCS1-0.4-50	0.0033	26	106	0.25	27	7
MRPCS2-0.4-50	0.0066	33	112	0.29		
MRPCS1-0.4-70	0.0033	43	189	0.23	0	-20
MRPCS2-0.4-70	0.0066	43	152	0.28		
MRPCS1-0.8-50	0.0033	32	119	0.27	12.5	3
MRPCS2-0.8-50	0.0066	36	122	0.29		
MRPCS1-0.8-70	0.0033	43	158	0.27	35	53
MRPCS2-0.8-70	0.0066	58	242	0.24		

Table 9. Effect of slab thickness on the ultimate failure load.

Slab Designation	Slab Thickness (mm)	P_{cr} (kN)	P_u (kN)	P_{cr}/P_u	ΔP_{cr} %	ΔP_u %
NCS1-0-50	50	9	29	0.31	20	49
NCS1-0-70	70	12	41	0.29		
NCS2-0-50	50	12	42	0.28	26	33
NCS2-0-70	70	15	56	0.28		
MRPCS1-0-50	50	21	73	0.29	50	75
MRPCS1-0-70	70	35	128	0.27		
MRPCS2-0-50	50	30	97	0.31	40.6	50
MRPCS2-0-70	70	39	146	0.27		
MRPCS1-0.4-50	50	26	106	0.25	48.6	78
MRPCS1-0.4-70	70	43	189	0.23		
MRPCS2-0.4-50	50	33	112	0.29	68.9	38
MRPCS2-0.4-70	70	43	152	0.28		
MRPCS1-0.8-50	50	32	119	0.27	36.7	33
MRPCS1-0.8-70	70	43	158	0.27		
MRPCS2-0.8-50	50	36	122	0.29	17.2	98
MRPCS2-0.8-70	70	58	242	0.24		

6.8. Effect of Flexural Steel Reinforcement (ρ)

Table **8** shows the effect of flexural steel reinforcement ratio on the behavior of normal and modified reactive powder concrete slabs in terms of load characteristics. Generally, for both types of concrete, the ultimate flexural capacity was enhanced by increasing the ratio of steel reinforcement.

For normal concrete, increasing flexural steel reinforcement ratio from (0.0033 to 0.0066) was improved with the ultimate failure load up to (45 and 37) % for slabs with (50 and 70) mm thicknesses, respectively. However, for MRPC slabs with thickness of 50mm and with steel fiber contents of 0,0.4 and 0.8, this percentage of increase was reached to (33,7 and 3) %, respectively. The enhancement of ultimate load capacity for MRPC slabs of the thickness (70) with steel fibers of 0, 0.4 and 0.8 was reached to 14,-20 and 53, respectively. Except for the specimen of MRPCS2-0.8-70, it is clear that when increasing the ratio of steel reinforcement, the enhancement in the ultimate load capacity was decreased, this may be due to that the failure mode was converted from tension failure to shear. The maximum increasing percentage of ultimate load was reached for the slab of thickness 70mm and had a higher content of steel fiber, MRPCS2-0.8-70, which delay propagation the cracks in shear zone, thereby, that permit to yield the flexural reinforcement and failed by tension mode, (Table **4**).

6.9. Effect of Slab Thickness

From the results shown in Table **9**, it can be seen that the ultimate flexural capacity was increased with increasing the slab thickness.

For normal concrete specimens, increasing slab thickness from (50) to (70) mm has increased the ultimate failure load by (49 and 33%) for slabs with flexural steel reinforcement ratio of (0.0033 and 0.0066), respectively. This is the percentage for slabs with 0.0033 flexural steel reinforcement (75, 78 and 33%) for MRPC slabs with steel fibers content (0, 0.4 and 0.8%), respectively. The improving percentage of the ultimate failure load for slabs with (0.0066) flexural steel reinforcement was (50, 38 and 98%) for MRPC slabs with steel fibers content (0, 0.4 and 0.8%), respectively. From Table **5**, it can be noted that the thickness of slabs had no effect on the mode of failure, excepted slab of MRPCS2-0.8-70, where the failure mode was transformed from tension-shear to pure tension failure due to high content of steel fiber in this slab.

From the results in Table **9**, for both normal and MRPC slabs, it is clear that the percentages of increasing the ultimate failure load for slabs with (0.0033) flexural steel reinforcement ratio were higher than of slabs with flexural steel reinforcement ratio (0.0066). This may be due to the slabs with (0.0033) flexural steel reinforcement ratio failed in tension mode, while the mode of failure in slabs with (0.0066) flexural steel reinforcement ratio was already shear mode. An excepted slab of MRPCS2-0.8-70 was failed by tension mode due to the high content of steel fiber in this slab.

CONCLUSION

From the results of the present experimental work, the following conclusion can be summarized:

[1] The mechanical properties of modified reactive powder concrete, in terms of compressive strength, splitting tensile strength and modulus of rupture, were better than that of normal concrete, especially when added the steel fibers to the concrete mixture.

[2] As compared with the normal concrete slabs, the percentage of increasing the ultimate load strength for MRPC slabs (without steel fibers) was reached to 212%.

[3] The slabs of steel reinforcement ratio (ρ) of (0.0033) were failed in tension mode, while the slabs of steel ratio (ρ) of (0.0066) were failed in a combined mode of tension and shear, highlighting that the slab of MRPCS2-0.8-70 was failed by tension mode due to inclusion higher steel fibers content.

[4] Adding the steel fibers to the concrete mixture of the MRPC slabs improved the ultimate load capacity up to (45 and 66) %, for slabs with steel fibers of (0.4 and 0.8) %, respectively, as compared to non- fibrous slabs.

[5] For both normal and MRPC slabs, an enhancement of the ultimate load was gained, when increasing the slab thickness, up to (49 and 98%), respectively, while this percentage has become (45 and 53%) when increasing the steel reinforcement ratio.

[6] The ductility of fibrous MRPC slabs was more than both slabs of non-fibrous MRP and normal concrete and failed gradually.

[7] Inclusion of the steel fiber in MRPC slabs enhanced their stiffness, reduced crack width and its numbers, reduced the rate of crack propagation as well as preserved the whole section together after reaching the failure. Most of the steel fibers were observed to pull out the cement matrix rather than snap.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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REFERENCES

[1] P. Richard, and M. Cheyrezy, "Reactive powder concretes with high ductility and 200-800mpa compressive strength", *American Concrete Institute,* vol. 144, pp. 507-518, 1994.

[2] K. Wille, A.E. Naaman, and G.J. Parr-Montesinos, "Ultra-High Performance Concrete with Compressive Strength Exceeding 150MPa (22ksi): A Simpler Way", *ACI Mater. J.,* vol. 108, no. 1, pp. 46-54, 2011.

[3] H.M. Al-Hassani, W.I. Khalil, and L.S. Danha, *Mechanical Properties of Reactive Powder Concrete with Various Steel Fiber and Silica Fume Contents.,* Acta Technica Corvininesis-Bulletin of Engineering, 2014, pp. 47-57.

[4] A. Al-Tikrite, and M.N.S. Hadi, "Mechanical Properties of Reactive Powder Concrete Containing Industrial and Waste Steel Fibers at Different Ratios under Compression", *Constr. Build. Mater.,* vol. 154, no. November, pp. 1024-1034, 2017. [http://dx.doi.org/10.1016/j.conbuildmat.2017.08.024]

[5] S. Collerpardi, L. Coppola, R. Troli, and M. Collepardi, "Mechanical Properties of Modified Reactive Powder Concrete", *Proceedings Fifth CANMET/ACI International Conference on Superplasticizers and the Chemical Admixtures in Concrete,* vol. 173, 1997pp. 1-21 Rome. Italy. Farmington Hills*MI: ACI publication*,

[6] T. Sujatha, and D. Basanthi, "Modified Reactive Powder Concrete", *Int. J. Edu. App. Res,* vol. 4, pp. 85-87, 2014.

[7] W.I. Khalil, "Some Properties of Modified Reactive Powder Concrete", *J. Eng. Dev,* vol. 16, no. 4pp, pp. 66-78, 2012.

[8] G. K. Manasa, CH. Venkata Ramana, and P. Sai Pradeep, "Study on

Properties of Modified Reactive Powder Concrete", *Int. J. Innov. Tech.,* vol. 5, no. 4, pp. 627-631, 2017.

[9] Y.J. Kum, and T.H. Wee, "Shear Strength of Lightweight Concrete One-Way Slabs", *32nd Conference on Our World in Concrete and Structures,* 2007 Singapore

[10] T.G. Kumari, C.G. Puttappa, C. Shashidar, and K.U. Muthu, "Flexural Characteristics of SFRSCC and SFRNC One-Way Slabs", *Int. J. Res. Eng.Tech,* vol. 02, no. 07, pp. 220-229, 2013. [http://dx.doi.org/10.15623/ijret.2013.0207030]

[11] C.R. Michaluk, S.H. RIzkalla, G.T. Tadros, and B. Benmokrane, "Flexural Behavior of One-Way Slabs Reinforced by Fiber Reinforced Plastic Reinforcement", *ACI Struct. J.,* vol. 95, no. 3, pp. 359-365, 1998.

[12] L. Ombres, T. Alkhrdaji, and A. Nanni, "Flexural Analysis of OneWay Concrete Slabs Reinforced with GFRP Rebars", In: *I. CrivelliVisconti,* Ed., Proceedings, Advancing with Composites 2000: Milan, Italy, 2000.

[13] L. Ombres, T. Alkhrdaji, and A. Nanni, "Flexural Analysis of OneWay Concrete Slabs Reinforced with GFRP Rebars", In: *International Conference on Composite Materials, Proceedings of Int,* Conference on Advancing with Composites 2000, Italy, 2000.

[14] B. Zhang, R. Masmoudi, and B. Bemmokrane, "Behavior of One-Way Slabs Reinforced with GFRP Grid Reinforcements", *Constr. Build. Mater.,* vol. 18, pp. 625-635, 2004. [http://dx.doi.org/10.1016/j.conbuildmat.2004.04.007]

[15] G.N. Vijayaprakash, R. Sivagamasundari, and G. Kumaran, *Flexural Behaviour of One Way Concrete Slabs Reinforced with Nonmetallic Fibre Based Reinforcement,* 2004.

[16] A. ElRagaby, E. ElSalkawy, and B. Benmokrane, "Fatigue Analysis of Concrete Bridge Deck Slabs Reinforced with Eglass/ Vinyl Ester FRP Reinforcing Bars", *J. Comp. Struc.,* vol. 11, no. 3, pp. 258-268, 2007.

[17] R. Sivagamasundari, and G. Kumaran, "A Critical Study on the Suitability of Glass Fibre Reinforced Polymer Reinforcements for Concrete One Way Slabs", *Proceedings of International Conference on Recent Developments in Structural Engineering RDSE,* 2007pp. 117-124 India

[18] R. Sivagamasundari, and G. Kumaran, "A Comparative Study on the Flexural Behaviour of One-Way Concrete Slabs Reinforced with GFRP Reinforcements and Conventional Reinforcements when Subjected to Monotonic and Repeated Loading", *Open Civ. Eng. J.,* vol. 2, pp. 24-34, 2008. [http://dx.doi.org/10.2174/1874149500802010024]

[19] M. Adom-Asamoah, and C.K. Kankam, "Flexural Behaviour of OneWay Concrete Slabs Reinforced with Steel Bars Milled from Scrap Metals", *Mater. Des.,* vol. 30, pp. 1737-1742, 2009. [http://dx.doi.org/10.1016/j.matdes.2008.07.048]

[20] R. Sivagamasundari, and G. Kumaran, "Experimental Study on the Behaviour of Concrete One Way Slabs Reinforced with GFRP Reinforcements under Constant and Variable Amplitude Repeated Loadings", *Int. J. Civil. Struc. Eng,* vol. 2, no. 2, pp. 547-569, 2011.

[21] K. Chang, and D. Seo, "Behavior of One-Way Concrete Slabs Reinforced with GFRP Bars", *J. Asian Archit. Build. Eng.,* vol. 11, no. 2, pp. 351-358, 2012. [http://dx.doi.org/10.3130/jaabe.11.351]

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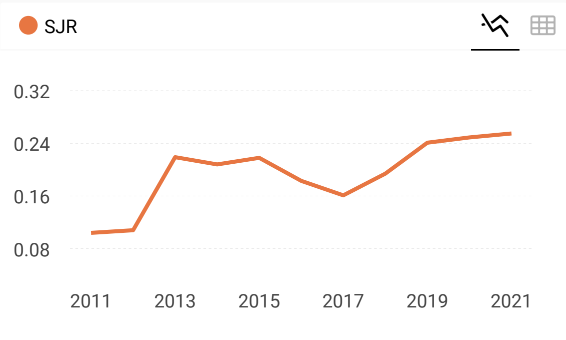

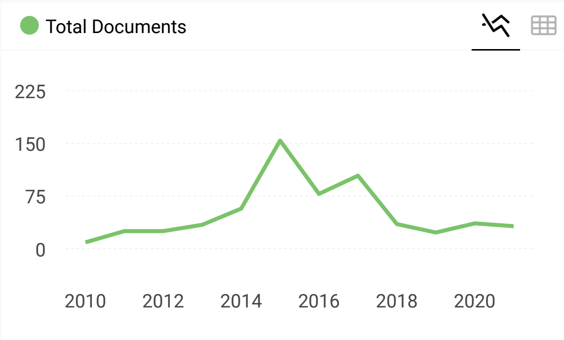

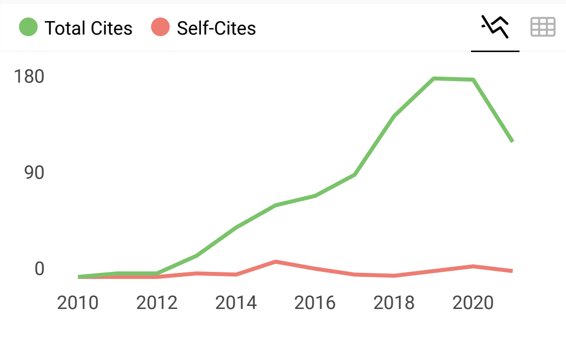

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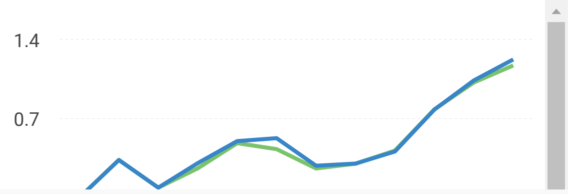

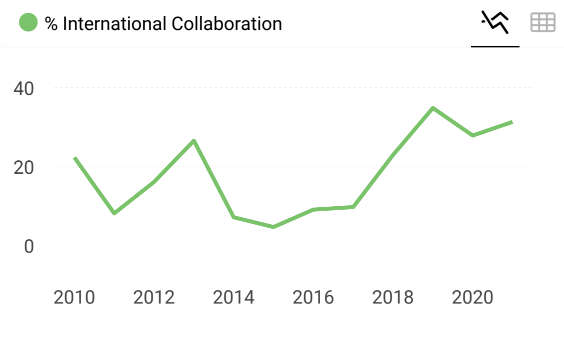

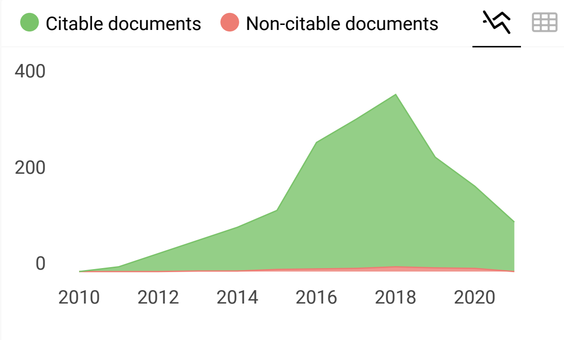

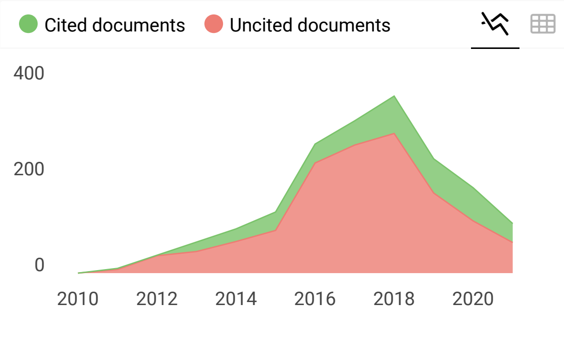

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