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# Investigating the Impact Resistance in RSNN Reactive Powder Concretes and Ordinary NSRN Concretes

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**ABSTRACT**

*Nowadays, the progress in the construction industry has seemingly made it necessary to use new and substitute materials. One of the materials used in concrete industry during the recent decade is the reactive powder concrete. The present study deals with the impact strength of this concrete considering the remarkable strength properties of this concrete. The samples included concrete beams with 120×120×120cm dimensions and their reactions to the free fall of a weight from a fixed elevation provide information that can be used as a good basis for comparing the concretes' impact performance. In order to measure and compare the behavior of the beams, use has been made of image processing software. The experimental samples include reactive powder concrete specimens with steel fiber without strengthening armature and FRP coating (RSNN) and the ordinary concrete specimens with steel fiber as well as shear armature and without FRP coating (NSRN).*

**Keywords:** *reactive powder concrete, steel fiber, impact, image processing software*

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## 1. INTRODUCTION

During the recent years and due to the world's current status and emergence of numerous wars and the increase in the terroristic attacks, attentions have been generally and increasingly directed at the safety of the engineering structures against the uncommon loads like explosions and projectiles' hit. Besides the abovementioned cases, the uncommon loads can stem from the vehicles' crash into the bridges' support, mountains' collapse on the bridges, projectiles brought by storm and tsunami and other similar cases that can influence the structure and its components.

Reactive powder concrete (RPC) is a new highly resistant concrete that was first introduced in 1994 by Bouygues Company (in France). This type of concrete has a lot of advantages in contrast to the ordinary and high-performance concrete types. Amongst the remarkable properties of this concrete, very high compressive strength (200 to 800MPa), high flexural strength (over 40MPa), high ductility (due to its containing of steel fiber), homogeneity (due to the omission of coarse gravels), low permeability and very long endurance can be pointed out.

Concrete and many of the constructional materials' failure and breakage is usually considered as a time-independent process. The effect of the loading speed and the strain rate is not taken into account in many of the concrete-related experiments and this results in approximate estimations of the results but such a presumption does not seem to be true regarding the dynamic loads with high loading speed and high strain rate such as during the projectile's hit and explosion as well as regarding the concrete's creeping phenomenon which usually takes place within several years. In dynamic loads, the loading speed is a very important factor largely influencing the behavior of the concrete and armature and the other constructional materials; in order to achieve reasonable results, the loading speed should be always taken into consideration in the masonry's behavior (Cusatis, 2011). In static loads and the loads with low strain rate, microcracks usually develop in the weak regions of the concrete such as in the contact surfaces between the stone masonry and cement as well as the pores and cavities that form in the cement matrix and turn into large cracks with the increase in the load rate following which the concrete undergoes fracture; however, in dynamic loads with high strain rate, due to the low loading period, holes and cavities appear in the constructional materials' contact to the cement matrix. In other words, the cracks do not have enough time in this state for choosing the weak paths inside the concrete (Mindess and Zhang, 2009). Thus, the increase in the strain rate and loading speed brings about an increase in many of the concrete's specifications like maximum compressive strength, tensile strength, elasticity module and compressive strength's equivalent strain and so forth (Lu and Xu, 2004). Besides concrete, most of the masonries like steel and FRP, as well, experience increases in the constructional materials' properties (tensile strength, elasticity module and so forth) with the increase in the strain rate.

Evaluation based on the realities of the load-bearing capacity and the general response of the reinforced concrete beams subject to the impact of the projectile is a very complex process. Laboratory studies are very costly and time-consuming in such a way that they are found solely performed in a few of countries. On the other hand, due to the fact that the contact process completes in a very short time (depending on the structure's type and its hardness, about a few milliseconds) and the imposed load is very high in comparison to the static loads and the structure often undergoes overall collapse during loading, the results obtained from the experiments do not have sufficient precision in many of the cases.

So far, many experiments have been carried out about the behavior of the reinforced concrete beams against concentrated loads with high loading speed. In the majority of these experiments, loading is carried out in such a way that a heavy steel weight (projectile) is released, depending on the intended loading speed from a fixed elevation, in free fall state to hit the middle point of the beam's span. The basis of all the laboratory studies is identical in this regard and the structurer is subjected to an impact by a heavy weight released in free fall state from a fixed elevation.

In studying the behavior of the beams with fiber concrete in response to the load stemming from the projectiles' hit, Wang et al (1996) dealt with the dynamic behavior of the concrete beams reinforced with three kinds of polypropylene, hooked-end steel and crimped steel fibers (Wang et al., 1996).

Fujikake et al (2009) performed studies on the behavior of the reinforced concrete beams in response to the impact load stemming from the projectiles' hit; the behaviors of the three beam types were investigated subject to dynamic loading stemming from the projectile's impact. The beams were loaded in such a way that a 400-kilogram weight was released from various heights in free-fall state on the beams (Fujikake and Soeun, 2009).

The studies by Kishi and Mikami in 2012 were about the designing of reinforced concrete beams for loads stemming from the projectile's hit using empirical formulas; in their studies, 36 experiments of weight's free fall in various speeds and energies on the concrete beams with different dimensions, cross sections and rebars were carried out for designing reinforced concrete beams that can stand the loads stemming from the direct projectile hit and, using the maximum beam responses (maximum impact force imposed, maximum displacement of the beams' mid-sections, maximum plastic displacement of the beams' mid-sections and maximum support reaction), relations were suggested for designing beams against the loads stemming from the projectile's hit based on the beams' static capacity (Kishi and Mikami, 2012).

In 2009 and in a research paper, Kabir and Shafe'ei dealt with strengthening of reinforced concrete beams against the low-speed impacts of the projectiles; in this study, the concrete beams were modeled using finite element method and ABAQUS Software. In order to subject the beams to dynamic loading, use was made of a 22.73-kilogram weight that was released in free fall state on the beams. Use was also made of CFRP composite in the upper and lower surfaces of the beams (Shafei and Kabir, 2009).

Studies by Arzul A. Mutalib, as well, were about the prediction and evaluation of RC structures reinforced with FRP against explosion and impact loading; in this study, the dynamic behavior of four types of beam was evaluated in terms of strength against the hit of a 92-kilogram weight. The specifications of the used constructional materials were also assessed before and after loading. Considering the laboratory facilities of Australia's Western University, the effects of two parameters were largely evaluated in this study, namely 1) the effect of the beams' strengthening method by CFRP composites and 2) beams' failure modes (Mutalib, 2011).

In order to investigate the impact strength of the reactive powder concrete and its comparison with the concretes usually applied in industry and also to introduce the reactive powder concrete to the building industry, especially in military usages, efforts have been made herein to perform impact experiments on various concrete samples which are in the form of beams and will be subjected to impact by weights released from a fixed elevation so that the response of each sample, i.e. its flexural failure, can be interpreted and compared through delineating longitudinal strain and creep diagrams.

## 2. MATERIALS AND METHODS:

Considering the fact that the use of reactive powder concrete has been just recently proposed in our country, the present research paper tries recognizing its behavior during responding to impact loading. To do so, two kinds of experimental samples have been utilized for comparing the impact response. The experimental samples include the reactive powder concrete specimens with steel fiber and without strengthening armature and RRP coating (RSNN) and the ordinary concrete specimens with steel fiber, shear armature and without FRP coating (NSRN).

It is worth mentioning that the armature used in the specimens is in longitudinal and shear forms, each 6mm in diameter; also, glass FRP has been stuck about the specimens for enhancing the shear strength. The comparison of the impact behavior of each of these samples gives useful results and will be followed by more innovations in the similar future projects.

**RPC Mixing Plan:**

Materials used for RPC are as outlined in table (1).

**Table 1:** mixing plan of reactive powder concrete

| Applied materials | Amount in kg/m³ |
|---|---|
| Cement | 850 |
| Silica sand | 935 |
| Silica powder | 180 |
| Micro-silica | 212.5 |
| Superplasticizer | 45 |
| Water | 204 |

**Table 2:** plan of mixing ordinary concrete with steel fiber

| Material | Amount in kg/m³ |
|---|---|
| Cement | 450 |
| Water | 117.5 |
| Sand | 920 |
| Coarse gravel | 880 |
| Micro-silica | 24 |
| Superplasticizer | 7.2 |
| Metal fiber | 58.87 |

**Method of Producing Reactive Powder Concrete:**

The mixing method of this concrete is very important and it has to be done with due care. After mixing the dry masonry, water and superplasticizer is admixed. The mixing should be carried out in such a way that the resulting mixture be completely uniform and homogeneous.

Temperature plays an important role in this concrete's curing. Studies have shown that many of RPC's characteristics can be improved through high-temperature curing. Furthermore, samples can be subjected to pressure before and during setting and this is also effective in improving their properties. Curing in temperatures between 20°C and 90°C gives a concrete with a strength rate of 200MPa. In temperatures above 200°C and under pressure, the samples' strength can be increased up to 800MPa. Subjecting the samples to pressure causes the elimination of the trapped air and enhancement of the samples' density. RPC needs pre-setting pressure and curing in temperatures between 250°C and 800°C and it can be solely used in precast elements. Furthermore, this material has an extraordinary impact strength rate and it can be used for military structures and equipment (Richard and Cheyrezy, 1995).

Newly mixed reactive powder concrete can be considered as a sort of mortar.

Cement used for RPC is of I-525 Shahr-e-Kurd Cement type; its physical and chemical properties have been respectively given in the following tables.

**Table 3:** physical properties of I-525 Shahr-e-Kurd Cement

| Standard | Blaine | Setting Time-Min | | Compressive Strength(kg/Cm2) | | | | %Autoclave |
|---|---|---|---|---|---|---|---|---|
| | Cm2/g | First | Last | Day2 | Day3 | Day7 | Day28 | Expansion |
| ISIRI-389 | ≥2800 | ≥45 | ≤360 | ≥200 | --- | --- | ≥525 | ≤0.8 |
| ASTM | --- | --- | --- | --- | --- | --- | | --- |
| BS EN 197-1 | --- | ≥45 | --- | ≥200 | --- | --- | ≥525 | --- |
| Shahrekord cement | ≥3200 | 85-110 | 110-190 | ≥200 | ≥240 | ≥350 | ≥530 | ≤0.20 |

**Table 4:** chemical properties of I-525 Shahr-e-Kurd Cement

| Standard | SiO2 | AL2O3 | Fe2O3 | Cao | MgO | SO3 | CL | InR | L.O.I | Total Alkali | F.Cao |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ISIRI-389 | - | - | - | - | ≤5.0 | ≤3.0 | - | ≤0.75 | ≤3.0 | - | - |
| ASTM | - | - | - | - | - | - | - | - | - | - | - |
| BS EN 197-1 | - | - | - | - | - | ≤4.0 | ≤0.10 | ≤5.0 | ≤5.0 | - | - |
| Shahrekord cmenet | 20.70-21.10 | 5.10-5.40 | 3.80-3.95 | 65.00-65.40 | ≤1.65 | ≤2.0 | ≤0.03 | ≤0.65 | ≤1.30 | ≤0.70 | ≤1.30 |

Silica sand used in this project has a diameter smaller than 0.7mm and it has been procured from Babak Silica Company.

Silica powder used in this study is of 120-mesh type which has the lowest percentage of basic materials in such a way that the concrete preserves its hardness for a long period of time.

Micro-silica used in this research has been procured from Azna in Lorestan Province and it has the following specifications.

**Table 5**: specifications of micro-silica used in the project

| Specifications of the used micro-silica |
|---|
| Factory Name: Azna (Lorestan Province) |
| Structure: non-crystalized (amorphous) |
| Particles' shape: spherical |
| Approximate diameter: 0.1 micron |
| Specific surface area: about 20m²/gr |
| Specific mass-bulk weight: 250kg/m³ |
| Color: gray, whitish and bright |
| Moisture percentage: at most 3% |
| Storage conditions: in dry and covered locations |

**Table 6:** chemical composition of micro-silica procured from Azna, Lorestan Province

| Material | $H_2o$ | SiC | C | $SiO_2$ | $Fe_2O_3$ | $Al_2O_3$ | CaO | MgO | $Na_2O$ | $K_2O$ | $P_2O_5$ | $SO_3$ | CL | LO1750C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Percentage | 0.8 | 0.5 | 0.3 | 96.4 | 0.87 | 1.32 | 0.49 | 0.97 | 0.31 | 1.01 | 0.16 | 0.1 | 0.04 | 0.94 |

Superplasticizer used in this study is of P10-3R Fercoplast type. P10-3R superplasticizer is the third generation based on modified polycarboxylate and it has been produced through reserving the concrete's slump properties during a long time. This superplasticizer has a mechanism of action as explained below:

**Impact Test:**
The experimental samples are concrete beams with 10×20×120cm dimensions. Each of the studied concrete types were constructed in several specimens and subjected to impact tests and they were found diversely responding thereto. In order to perform the impact test, a devise was manufactured as shown in figure (1). The weight used in the experiment weighed 115kg and it was released from a 30-centimeter elevation on the specimens. The device has been designed inn such a way that the supports on the two heads of the beams can act as simple joints.
The number of the impact times, cracking style of the beams, longitudinal strain and creep of the beams are good scales for discussions about their impact behaviors.

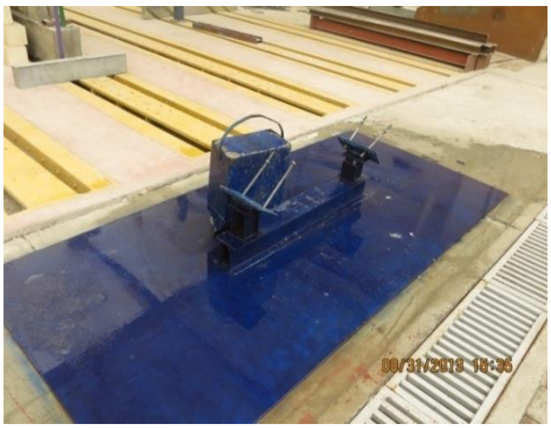

**Figure 1:** a view of the laboratory setup

**Image Processing Software:**
Due to the unavailability of dynamic strain gauge, the authors were forced to use image processing method for determining the longitudinal strain as well as creeping of the beams. To do so, use was made of MATLAB program for writing codes with its performance method being transformation of the film to numerous frames and following the trend of variations in the specification of the spots in each frame. After making a film of every experiment using a camera capable of recording 1200 frames per seconds and introducing it to the program, useful results were obtained with acceptable error rates.

## 3. RESULTS AND FINDINGS:

According to the results obtained from image-processing software, the impact response of various kinds of concrete can be investigated from various perspectives. In the investigation of the results, diagrams were delineated for exhibiting the longitudinal strain and creeping variations in every impact imposed on the concrete beam.
Moreover, the three bar diagrams were drawn for general comparison of the concrete samples. As for the specimens that broke with the first impact, no creeping and strain is defined. It is worth mentioning that the delineated diagrams indicate the average laboratory results for each sample.

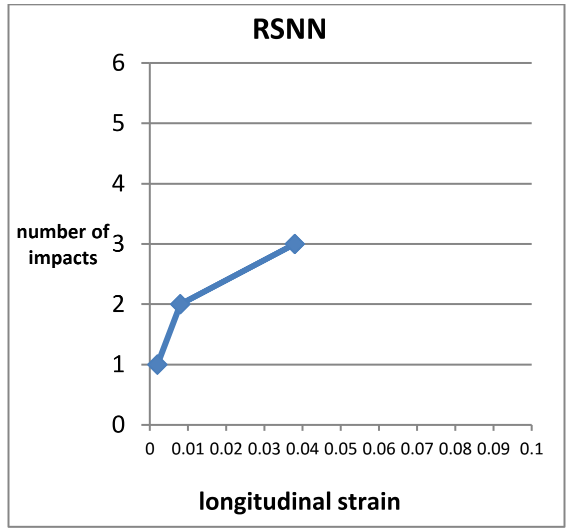


**Figure 2:** longitudinal-impact strain for RSNN concrete

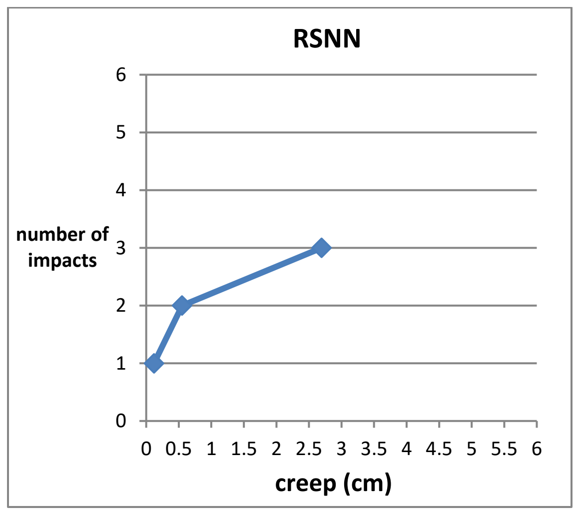


**Figure 3:** diagram of creeping-impact for RSNN concrete

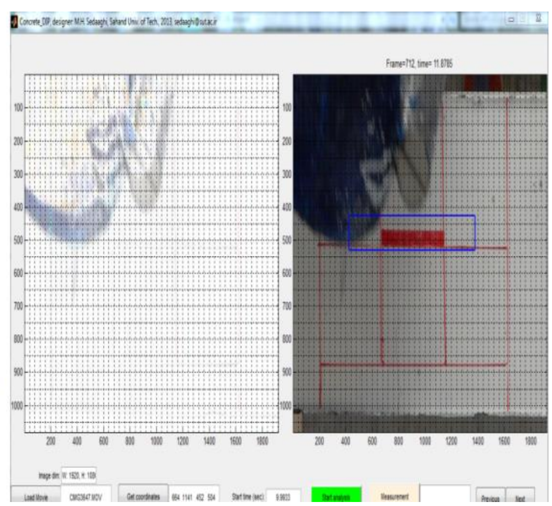

**Figure 4:** software output for the first impact on RSNN concrete

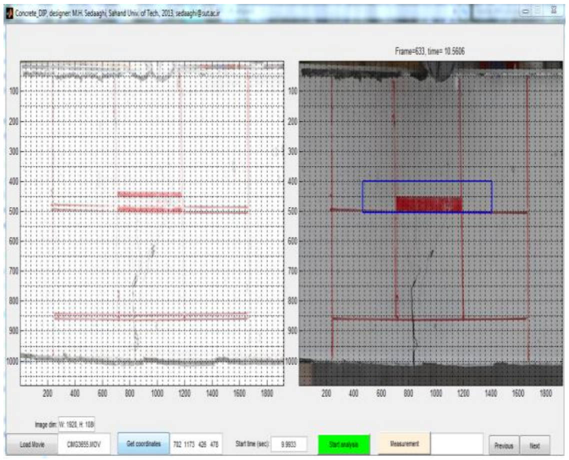

**Figure 5:** software output for the second impact on RSNN concrete

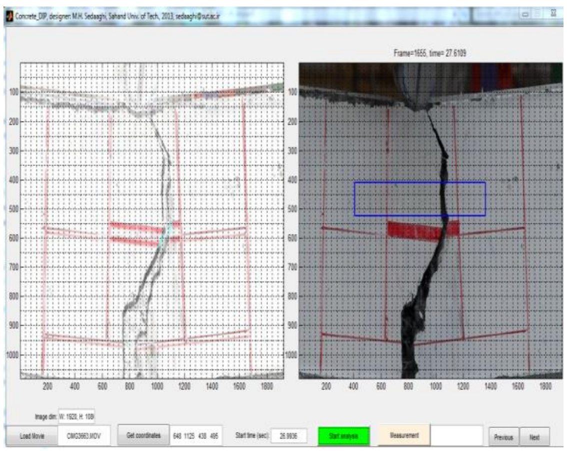

**Figure 6:** software output for the third impact on RSNN concrete

It is observed in the diagram in figure (7) that HSRN sample undergoes disintegration in four stages due to the existence of steel fiber.

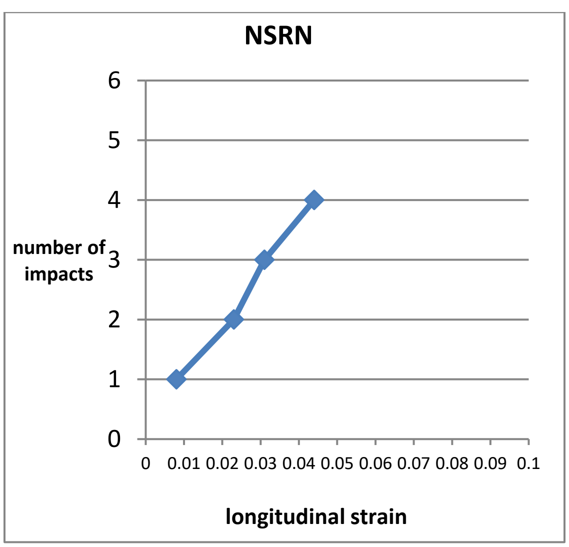


**Figure 7:** longitudinal-impact strain of HSRN concrete

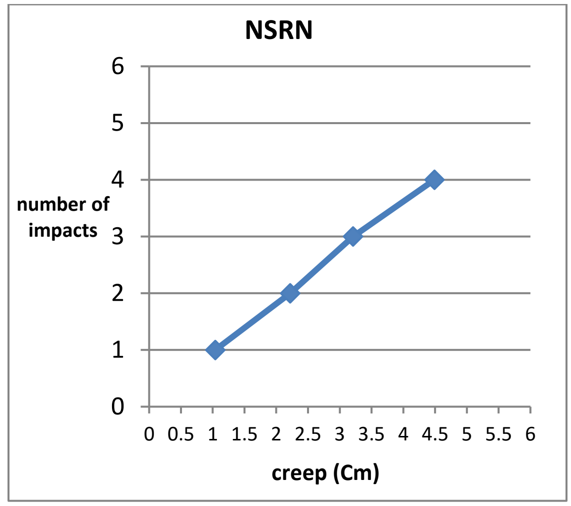


**Figure 8:** diagram of creeping-impact for NSRN concrete

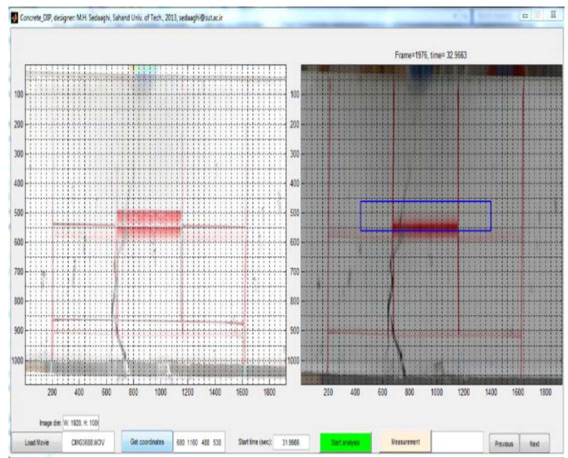

**Figure 9:** software output for the first impact on NSRN concrete

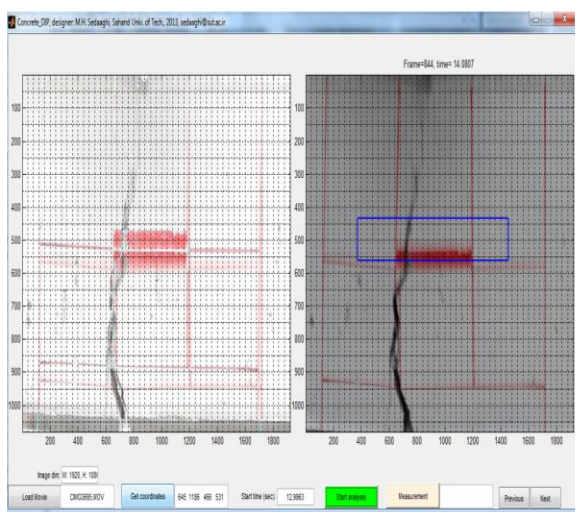

**Figure 10:** software output for the second impact on NSRN concrete

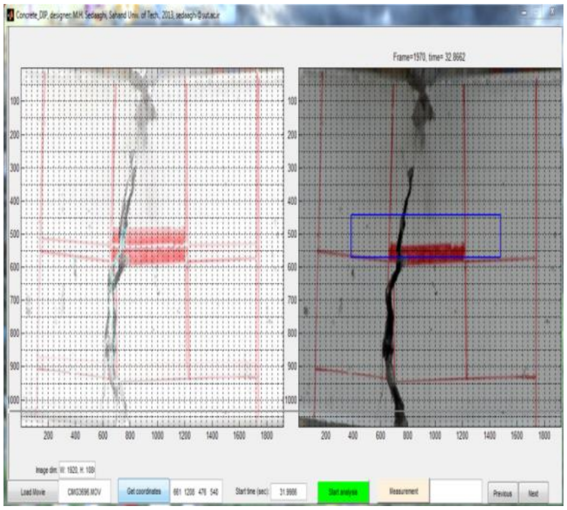

**Figure 11:** software output for the third impact on NSRN concrete

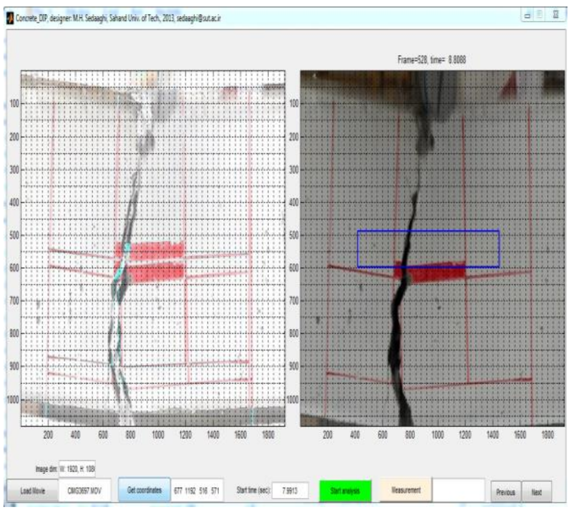

**Figure 12:** software output for the fourth impact on NSRN concrete

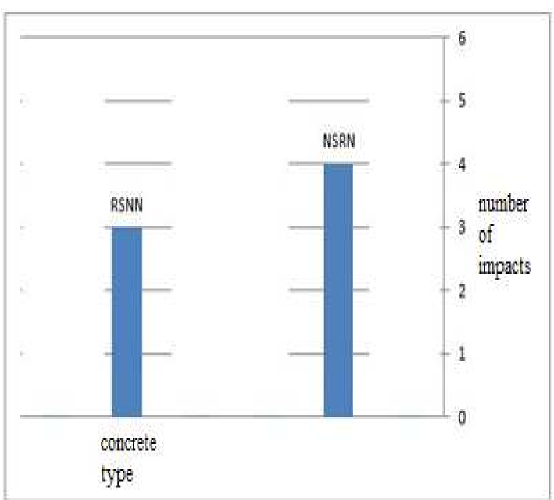


**Figure 13:** diagram of comparing the concrete type versus impact times

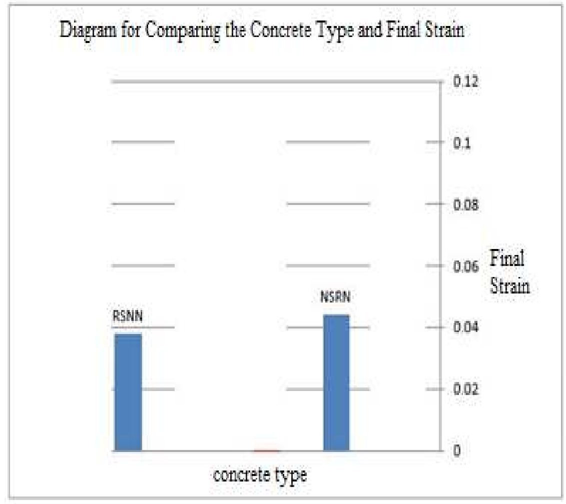


**Figure 14:** diagram of comparing the concrete type versus the final strain

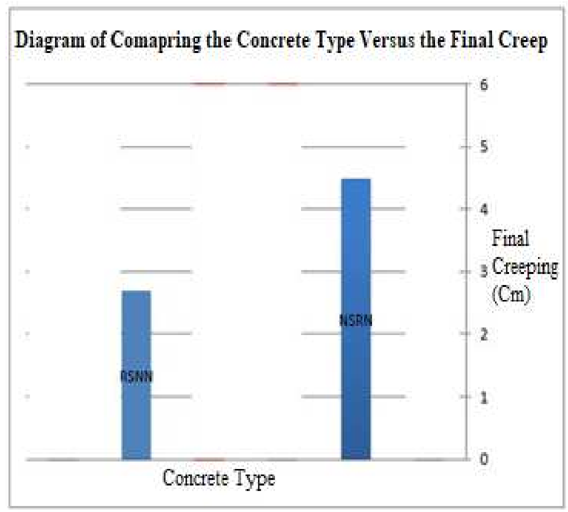


**Figure 15:** diagram of comparing the concrete type versus the final creep

## 4. DISCUSSION AND CONCLUSION:

Reactive powder concrete that has been recently introduced in our country can provide notable results with its unique properties; more concentration on its results and further improvement of them can be followed by a lot more optimum results.

Unlike its fiber-free counterpart, reactive powder concrete with steel fiber can tolerate three impacts. It is evident that the only factor causing such a notable difference is the existence of the steel fiber. Application of the steel fiber largely increases the properties of the reactive powder concrete. The cracks formed in the first impact in RPC concrete were very tiny and they can be found in capillary forms along the length of the beam. Moreover, the longitudinal strain and initial creep of the beam is very trivial in comparison to the other specimens. The role that the fiber plays in the ordinary concrete is not as notable as its role in the reactive powder concrete. No use has been made of strengthening armature in the powder concrete sample but this shortcoming can be compensated by the inherent properties of the concrete itself and the steel fiber provided that the curing procedures are optimally carried out for the concrete's production. Variable use of fiber coating in the samples can result in diverse and useful comparison scales.

**REFERENCES**

1. Cusatis G. Strain-rate effects on concrete behavior. International Journal of Impact Engineering. 2011 Apr 1;38(4):162-70.
2. Fujikake K, Li B, Soeun S. Impact response of reinforced concrete beam and its analytical evaluation. Journal of structural engineering. 2009 Aug;135(8):938-50.
3. Kishi N, Mikami H. Empirical Formulas for Designing Reinforced Concrete Beams under Impact Loading. ACI Structural Journal. 2012 Jul 1;109(4).
4. Lu Y, Xu K. Modelling of dynamic behaviour of concrete materials under blast loading. International Journal of Solids and Structures. 2004 Jan 1;41(1):131-43.
5. Mindess S, Zhang L. Impact resistance of fibre-reinforced concrete. Proceedings of the Institution of Civil Engineers-Structures and Buildings. 2009 Feb;162(1):69-76.
6. Mutalib AA. Damage assessment and prediction of FRP strengthened RC structures subjected to blast and impact loads. University of Western Australia; 2011 Dec.
7. Richard P, Cheyrezy M. Composition of reactive powder concretes. Cement and concrete research. 1995 Oct 1;25(7):1501-11
8. Shafei E, Kabir MZ. Analytical and Numerical Study of FRP Retrotted RC Beams Under Low Velocity Impact. scientiairanica.;16(5):0-.
9. Wang N, Mindess S, Ko K. Fibre reinforced concrete beams under impact loading. Cement and concrete research. 1996 Mar 1;26(3):363-76.