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A State of the Art Review on Reactive Powder Concrete Slabs

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Abstract

In recent decades, there have been many improvements and enhancements in concrete technologies which had an impact on structural systems. In the form of superplasticizer, the cement mixture is used with silica fume in place of a pozzolanic material (silica fume) and steel fibers, and is classified as ultra-high strength concrete in order to improve the structural behavior of the slabs. This review describes previous research literature relating to RPC mechanical properties and RPC slabs. So far, there are no available official design codes on RPC. Previous studies related to the present research can be categorized according to the historical background and development of RPC and its mechanical properties.

Keywords: experimental, reactive powder reinforced concrete, slabs, steel fiber, theoretical.

INTRODUCTION

Analysis and design of reinforced concrete slabs are interactive areas of research work. For the first time, Reinforced concrete slabs were casted based on a regular standard at the start of the twentieth century. Reinforced concrete slabs are familiar structural members. It is a component of the building structure that generally surrounds a space vertically. They can provide the lower support panels (floor) or top construction (roof) in any panel in the structure. It would be noted that only the core or structure part of this type of construction is classified as a slab. Slabs are built in different types: e.g., pre-cast or compound with many kinds' structural systems as solid, voided, ribbed, and waffle.

Generally, the situation occurs that structural members have to be renovated because of many issues, or for specific instances. One of the extremely common problems the necessity for openings to be generated in some cases when allocating with reinforced concrete slabs; the essential for openings in slabs becomes encountered in the structural engineering. Post-construction fixing of elevator or escalators, introduction new staircases, heat and ventilation ducts, fire protection of pipelines, additional skylights plumbing , air conditioning, benefits (electricity, telephones and wiring ducts) and architectural aspects are required over the flooring slabs [1].

Reactive Powder Concrete (RPC)

The Reactive Powder Concrete (RPC) material was invented in France in the early 1990s. The first RPC structure in the world (the Sherbrook Bridge in Canada) was constructed in July 1997. Reactive Powder Concrete (RPC) is define as an ultra-high-strength and high ductility cementitious composite with improved mechanical and physical characteristics. It is a special concrete in which improved by microstructure through accurate gradients of all particles in the mix to produce maximum density. The pozzolanic properties of using very fine material (silica fume) and optimization of Portland cement chemical properties to create the highest strength hydrates [2].

In the last years, significant improvement was achieved to develop different kinds of concrete. Technologies characterize the RPC as a kind of technical revolution compared to the familiar concretes. Special types of developed concrete are the steel fiber concrete (SFC) and high strength concrete (HSC). Additionally the high-performance concrete (HPC) which is developed when the strength is not the most important factor, This material which is lately available demonstrates the high improved durability and strength characteristics compared to familiar or high-performance concrete and is categorized as ultra-high performance concrete (UHPC). The most significant improved "High Tech" materials are RPC as described by [3].

A type of this new cement-constructed composite material of superior enhancement and ultra-high strength is identified as RPC. A specific amount of short steel fibers can be used in the RPC mixture and durability matrix to enhance the RPC and to overcome the difficulty of high instability. RPC has been quickly utilized in many construction fields like bridge erection, high rise building and mining engineering [4].

The three commercial names of UHPC or RPC can be summarized as in Figure (1) [5]

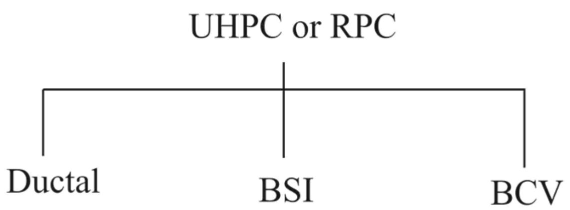

Figure 1 Schematic diagram showing types of RPC [5]

Ductal is produced in France through Lafarge Company having a compressive strength in the variety of 100- 200 MPa. A similar kind of concrete is called commercially Béton special industrial (BSI) concrete. This is a self-setting, fiber reinforced concrete that was offered by the firm Eiffage construction in association with Sika. Direct tensile strength of this concrete ranges from 8-10 MPa for 28 days age was obtained, and the characteristic compressive strength is found to be 150 MPa Brandt, A.M., in 2008 [6].

A third UHPC called BCV (Béton Composite Vicat) is industrialized by the cement manufacturer Vicat and Vinci group Resplendino, J., in 2004[7]. The concept of RPC is followed on the basis that materials with a minimum damage or defect, like small cracks, internal spaces which will have better load carrying capacity and larger capacity to withstand.

Structural designers continually pursue new construction methods and ideas that will make their buildings beautiful attractive, functionally effective, and cost efficient. Historically, the improvement in the structures depended strongly upon the characteristics of engineering materials. A new kind of material with excellent properties usually results in a revolution in structure, construction; this is true for steel structures and concrete structures as well. However, the structure cannot be designed with new materials, such as RPC, without developing new design criteria for RPC structures must be done to make use of the materials possible, with regular design references that do not deal fine by non-conventional resources. In several countries, the compressive strength of concrete which is greater than 80MPa not possible to use since present codes limits extra strength. Therefore that required to do search about the mechanical characteristics of RPC beams, slabs, columns, etc.

Richard and Cheyrezy in (1995) indicated the following principles for improving material RPC [2]

1- Enhancement of homogeneity by removing coarse aggregates from the mix
2- Employment of the pozzolanic characteristics of silica fume
3- Improvement and development of compacted concrete density by Optimization of the granular mixture
4- Enhance the workability of pressure (before and throughout setting) in order to develop compaction and reduction w/c ratio by the optimal usage of superplasticizer
5- After setting through the temperature treatment will lead to enhancement of the microstructure
6- Improvement of ductility by adding steel fibers of small-sized

Development, Mechanical Properties of RPC and RPC slabs

RPC first construction goes to the Richard and Cheyrezy, in (1994, 1995) [2, 8] when the first papers were available in 1994 and 1995, respectively. According to these papers, two classes of RPC were manufactured with target compressive strength of 200 MPa and 800 MPa. The properties of the mixture and the mechanical characteristic resulting from these two types of RPC are shown in Table 1. It was recommended that the size of maximum aggregate in UHPC is less than 600 μm.

Table 1. RPC 200 and RPC 800 mixtures from (Richard and Cheyrezy) [2] and [8]

	Type I (RPC200)				Type II (RPC800)	
Composition	Non Fibered		Fibered		Silica aggregate	Steel aggregate
Portland Cement	1	1	1	1	1	1
Silica fume	0.25	0.23	0.25	0.23	0.23	0.23
Sand 150-600 μm	1.1	1.1	1.1	1.1	0.5	-
Crushed quartz $d_{50} = 10\mu m^*$	-	0.39	-	0.39	0.39	0.39
Superplasticizer	0.016	0.019	0.016	0.019	0.019	0.019
Steel fiber L=12mm	-	-	0.175	0.175	-	-
Steel fiber L=3 mm	-	-	-	-	0.63	0.63
Steel aggregate <800 μm	-	-	-	-	-	1.49
Water	0.15	0.17	0.17	0.19	0.19	0.19
Compacting pressure	-	-	-	-	50MPa	50MPa
Heat treatment temperature	20 °C	90 °C	20 °C	90°C	250-400°C	250-400°C
Mechanical properties						
Compressive strength of cylinders	170-230 MPa				490-680MPa	650-810 MPa
Flexural strength	30-60 MPa				45-141 MPa	
Fracture energy	20000- 40000 J/m^2				1200-2000 J/m^2	
Ultimate elongation	$5000 \times 10^{-6} - 7000 \times 10^{-6}$mm				-	
Young's modulus	50-60 GPa				65-75 GPa	

Aitcin, in 1998 [9] defined the concrete as "high strength" based on its compressive strength measured at a specified age, but with the progress in research studies, the concrete which called high-strength is now named high performance concrete and this is due to not only to its strength but because: it gives enhanced performance such as durability and corrosion resistance. In the last decades, significant steps have been made in the development of higher strength concrete types in the form of High Performance Concrete (HPC), Very High Performance Concrete (VHPC) and Ultra High Performance Concrete (UHPC).

Jungwirth, J., in 2002 [10] investigated the influence of RPC heat treatment specimens at 90o C, as compared to the specimens which is moist cured at a 20o C on compressive and splitting tensile concrete strength. The selected results show that when the heat treatment at 90o C achieved, a rise for compressive strength range from 120 to 180 MPa, and for splitting tensile strength from 25 to 35 MPa are obtained. The RPC mixtures contained 638 kg/m3 of cement, 1085 kg/m3 furnace sand, 239 kg/m3 silica fume, 157 kg/m3 steel fibers with l/d 25/0.16, w/c of 0.23 and 23.7 kg/m3 of superplasticizer.

Silvia et al, in 2003 [11] investigated the influence of different fibers kind on the RPC behavior. The RPC mixture was made from (904 kg/m3) cement, (226kg/m3) silica fume, (944 kg/m3) sand and particle size from 0-1mm, (12.3 kg/m3) of superplasticizer, w/c ratio 0.24. Also, the mix contained (181 kg/m3) of steel fibers. Various kinds of fibers; brass plated steel (13/0.18), deformed steel (30/0.45), deformed steel (30/0.62) and deformed galvanized steel fibers (30/0.62). The results specified when use the brass plated fibers in the mix of the RPC offered a compressive and flexural strength higher than RPC having fibers of different types.

Voo et al, in 2003 [12] studied various samples of RPC using the two-point flexural tensile strength test. The prisms attained on 100mm square sections with span of 400 mm. The used types of steel fibers in these prism tests consisted of either 13mm straight fibers and/or 30mm end-hooked fibers and filled 2% by volume of concrete. The flexural strength of 23.2MPa was obtained for straight fibers and 25.2MPa for end hooked fibers. Their results indicated that an increase in their strength by about more than (8%) for fibers with end hooked related to straight fibers.

Al- Wahili, in 2005 [13] studied the mechanical properties of RPC properties of ash in addition to rice husk.The concrete samples was under compression and exposed to various stages of thermal curing when it was hardened. The mixture consists of ordinary Portland cement, very fine sand (less than 600µm) and rice husk ash. In this investigation, a dose of 10 %, 15 %, and 20 % of rice husk by cement weight, steel fibers and high range water was decrease the admixture at optimum amount of dosage. Results demonstrated which was probable to create a concrete having compressive strength equal 132MPa, flexural strength equal to 19.1MPa, dynamic modulus equal to 48.61GPa. The water absorption was 0.3kg/m2 in 15 days.

Jeffery et al, in 2006 [14] studied the structural behavior and performance of five normal and synthetic fiber reinforced concrete slabs of dimensions (2.2x2.2x0.15) m under flexural loading. Two volumes of fractions fibers (0.32% and 0.48%) were used. Results specified that the addition of fibers does not alter the first crack load of plain concrete slabs, but the flexural cracking load of normal concrete increases by (25% and 32%) and the ultimate load capacity of normal concrete increases by (20% and 34 %) with the addition of fibers by volume of fraction of (0.32% and 0.48 %).

Ali, in 2006 [15] aimed in part of his work to modify RPC by including some coarse aggregate, styrene butadiene rubber (SBR) polymer to substitute the superplasticizer and high reactivity metakaolin (HRM), as an active mineral powder to be used as alternative to the silica fume. The natural aggregate (maximum size 10mm) which were used to substitute the fine aggregate and/or part of the binder; this led to W/C and W/(C+HRM) ratios to be increased, while compressive, splitting tensile and flexural strengths had a little decrease.

Thomas et al, in 2007 [16] investigated the impact of adding fibers on mechanical characteristics of concrete. The models were derived through established 60 data of test results by the regression analysis for different mechanical characteristics of steel fibers reinforced concrete. Characteristics of the different strengths are the cube and the cylinder compressive strength, the tensile strength (modulus of rupture) modulus of elasticity, post cracking performance, Poisson's ratio, and the strain at peak compressive stress results. The strength of reinforced concrete which contains steel fibers was related using the recommended prototypes with the test data obtained from the study and with the various other test data cited in literature. The variable which is considered are strength of concrete, that is, 35 MPa, 65 MPa, 85 MPa for normal strength , moderately high strength , high-strength concrete respectively, and steel ratios content are Vf =(0, 0.5, 1.0, and 1.5%). The recommended mode predicted the test significantly data quite accurately. The research specifies that the contact of the fibers matrix involved to the improvement and development of mechanical characteristic resulting from the outline of fibers, that differs from current models and combinations based on the mixtures.

Husain in 2008 [17] modified an original reactive powder concrete (ORPC) which included a superplasticizer cement mixed and contained silica fume and fine steel fibers by using local metal admixture as high reactivity metakaolin as a replacement for silica fume, the steel fibrous was substituted with polypropylene fibers (PPF), and the part of mechanical characteristics improved the compressive and flexural strengths of MRPC and was enhanced punching shear and flexural strengths of normal and reinforced concrete flat plates. It was found that addition of PPF has increased the mechanical properties, where the cracks were more accurate and larger amount than normal and slabs reinforced didn't contain fibers. The research results showed increase in ultimate load of rupture for non-reinforced MRPC slabs (without fibers) by 50% while for the reinforced MRPC slabs (without fibers) by about 17% in punching shear strength, where the strength of concrete increases by 11.6%.

Also, the punching shear strength is enlarged by about (5-46) % compared to reinforced concrete slabs discluding fibers, while the enlargement in flexural strength alternated between 6.1 and 41 %., the ultimate load of fiber reinforced concrete slabs were greater than panels discluding fibers.

Ibraheem, in 2008 [18] presented an experimental research to found the widespread compressive stress-strain relations below the difference in pozzolanic material type, silica fume, metakaolin. The use of high-volume of fraction of steel fibers and silica fume in the mix of RPC increase the compressive strength, durability, ductility and density of the concrete and decreases its absorption. To develop an equation for determined the nominal flexural moment capability of RPC reinforced rectangular units, an ideal compressive stress block for RPC sections were recommended and used under the bending moment. Also, the results of the experimental research showed that reactive powder concrete mixtures with the silica fume provide the maximum value of compressive strength, density and less rate of absorption as compared to compressive strength ranges from (164-195) MPa.

Fernando et al in 2009 [19] presented and developed an ideal model of (SFRC) steel fiber reinforced concrete to be used in plate elements. These elements were recognized to their cracks, the fiber content and the load system were considered as variable in this investigation. The study used four different fiber contents and three different load systems. For each combination, three plates were tested giving a complete of 36 units. The fiber contents were 0, 50, 70 and 90 kg of fibers/m3 of concrete and the load systems were as shown in Figure 2. the finite elements model showed good association with respect to the experimental results. The model is capable to simulate the answer in the cracking process, involving a fast stress decrease and a stress increase after cracking. The fiber addition does not characterize a relevant improvement to the development of the compression strength of the concrete.

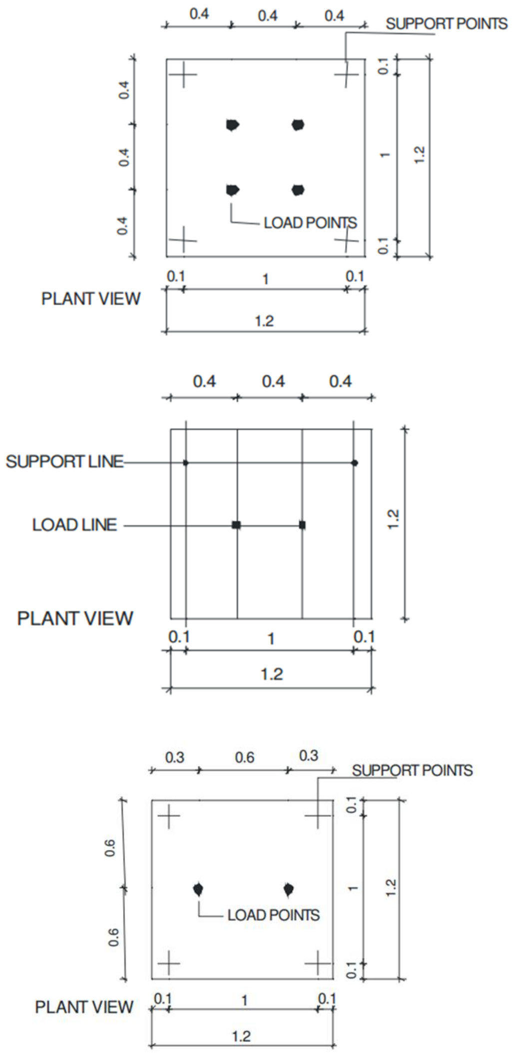

Figure 2 Type of loading on plate elements [19]

Shahidan, in 2009 [20] studied the influence of using steel fibers on the performance of laminated reinforced concrete slabs through computer simulations. In this investigation, the imitation of limited elements for the analysis of ordinary reinforced concrete slabs and steel fiber reinforced concrete slab due to different percentage of 1%, 1.5%, 2%, 2.5% and 3% of fibers. The loading was applied by gradual increase of every 2 kN up to collapse. The analysis result indicated that using steel fibers in reinforced concrete will affect the concrete ductility, toughness, energy absorption and concrete compressive strength. The aims of the research were to compare the finite element simulation analysis in established experimental work and to compare the properties of strength between normal and SFRC (steel fiber reinforced concrete slabs).

Hassan in 2012 [21] studied the mechanical characteristics of RPC and modified RPC (replacing 50% of fine sand by coarse aggregate) as a material in addition to study the influence and behavior of the punching shear which effected on the RPC and MRPC slabs. The research work contains testing of simply supported reinforced reactive powder concrete slabs requiring dimensions of (1000x1000x 50 or 70 mm) below concentrated load at the center of slab. Compared to normal strength concrete (NSC), it was initiate from the experimental tests that using Vf by 2% increases cube and cylinder compressive strength for RPC by about (176.57 and 214.66)%, respectively. For MRPC the respective ratios were (155.53 and 180.80) %. Percentages of increase (compared to NSC) are respectively for RPC and MRPC, for splitting tensile strength by (308.26 and 296.58) % and modulus of rupture (405.54 and 334.60) %, respectively.

The result of experimental work showed significant effects of RPC and MRPC on punching shear strength of slabs. The final load of RPC slabs was increased between (39.05-181.50) % over NSC slabs, and the final load between (63.81-138.50) % which is for MRPC slabs. The ultimate strain of RPC and MRPC slabs indicated that the increase in fiber ratio will lead to increases in the ultimate tensile strain between (15-99%) and decreases the ultimate compressive strain between (1.5-33.3%). When adding of steel fibrous, the deflection at final load is significantly enlarged. The steel fibers addition to RPC slabs results in an increase in load in the center at ultimate load between (93.7-283.8) %, and between (122.8-255.9%) for MRPC slabs.

Al-Jubory in 2013 [22] carried out experimental study on normal RPC and RPC reinforced (of 1% and 2% steel fibers) to measure the compressive strength, flexural strength and splitting tensile strength are associated, by using local obtainable material treated at 20°C and 80°C. The investigational research was worked on two sets of specimens. All the sets involved of (54) cubes with dimensions (50x50x50mm), (18) cylinder with dimensions (100x200mm) and (18) prism with dimensions (50x50x300mm). The results specified that the compressive strength is 74 MPa when use about 2% of steel fibers in which treatment at 20°C. When adding steel fibers by about 1% and 2% will lead to increase in the compressive strength, flexural strength, splitting tensile strength and the result which obtained are as follows

1. Compressive strength reached up to 70 MPa that equaled to 30% of compressive strength of RPC 200 of Richard and Cheyrezy. This result might be attributed to the high content of C3A in local cement while RPC 200 has free C3A.
2. Adding of steel fibers will increase the concrete compressive strength, flexural strength and splitting tensile strength.
3. Curing at high temperature water 80 °C increased the compressive strength at early ages and decreased it at 28 day as compared with curing at 20 °C.
4. The treatment in normal water at 20°C provides the compressive strength about (57-65) % at 3 days from the compressive strength of concrete of 28 days while about (75) % of 28 days compressive strength for 7 days. While the compressive strength in treatment with water of 80°C about (80-90) % of that of 28 day for 3 days, and at 7 days is about (93-97) % of that of 28 days was obtained.

5. Qasim in 2013 [23] tested 31 specimens (21 one way slab and 10 of two way slabs. Several important parameters were chosen to study their effects on experimental, finite element and analytical program for behavior and performance of reinforced RPC slabs with openings. These parameters are (five steel fiber contents, three silica fume contents, and three reinforcement ratios, two opening locations, four sizes and three shapes, grade of concrete and elements number) in terms of load deflection response, moment-curvature response, failure load, strain in concrete, strain in steel and cracking pattern. In general a good accord concerning the finite element solutions, analytical program and experimental results was found.

Results of experimental, analytical and finite element presented that the increases in steel fiber contents and silica fume lead to an increase the ultimate load and thus lead to increase in the deflection at failure load and curvature while more content of steel ratio may cause to greater load at failure and less content of both deflection at failure and curvature. Moreover, flexural toughness increased with the increase in fibers content and silica fume contents.

Danha et al, in 2015 [24] examined the compressive stress-strain relationships of RPC experimentally and a general equation for stating such relations is obtained. The effects of three different factors on the compression behavior and performance were considered in which superplasticizer, the silica fume content (0%, 10%, 15%, 20%, 25%, and 30%) as a part of replacement by cement weight, volume fraction of steel fibers Vf (0%, 1%, 2% and 3%) were used.

The results of the experimental work by (relationship of stress and strain) which is found for various RPC mixtures indicated that the increase in the silica fume content made the compressive stress-strain curve to develop more steeper giving a higher modulus of elasticity. It was established that adding steel fibers marginally increased the slope of the rising slope of the stress-strain curve, but there was a clear increase in strain at peak stress and an increase in ductility in addition to an obvious increase in compressive strength, but there was no obvious effect on the corresponding strain value.

The recommended equation which is be used safely in design and analysis when the proposed nonlinear equation for showing the widespread compressive stress-strain relationship of reactive powder concrete indicated a nearby accord with investigational results.

Majeed et al, in 2015 [25] studied (6) samples differed only in the voids volume Vv , the volume of steel fibers (Vf) and at that moment use carbon fibers for supported. Also the aim of enhancement by fibers, carbon polymer (CFRP) was found out to be effective structural members. The results of prototypical tests that were rehabilitated by use carbon fiber (CFRP), compared with the same samples before strengthening and tested will lead to reduce the failure, increased extreme durability, with the increase ranging from (51.6% to 96.2%). When treated after the failure and the correct use in the happening of the failure in whole or in part in the ceiling, and tested by using the same way and condition where the slabs was examined through it, is knowing that ceilings was strengthened and functioned in the same way.

This study concluded it is feasibility to use HCS for constructions as a floor and roofing system. It was showed also that these slabs efficient after rehabilitation using carbon fiber (CFRP) strips.

Qaseem in 2015 [26] performed an experimental work of punching shear for six reduced scale reinforced concrete slab specimens distributed into two groups (square and trapezoidal slabs) behavior. All specimens of slabs were prepared with square shaped and having dimensions of (450x450)mm and thickness of 50mm),While, the trapezoidal slabs were made with dimensions (450mm) width, (620mm) length, (50mm) thickness and the upper side was made with (200mm) width.

Each group consisted of three specimens that were identical in size and shape but contained different percentages of steel fibers (0, 0.5 and 1) % of total volume. The results showed that the punching shear strength increased by about (62.5% and 100%) for square slabs and it is about (8.3% and 41.7%) for trapezoidal slabs having (0.5% and 1%) of steel fibers respectively as presented in Figure 3.

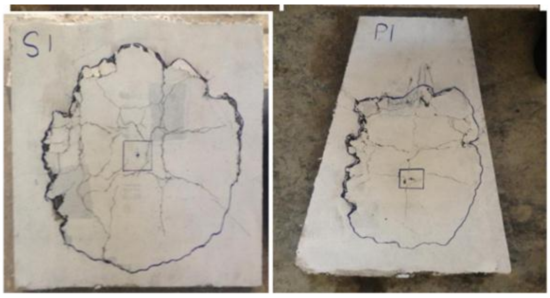

Figure 3. Failure pattern of flat slab samples [26]

Gholamhoseini et al in 2016 [27] studied sixteen full-scale continuous slab samples having different kinds of bonding between the concrete slab and steel decking (e.g. greased, standard decking) with various types and quantities of reinforcement in concrete (such as steel fibers, mesh or ordinary reinforcement). The slabs were 6.3m long, 1.2m wide and 0.15m thick involving of two distances of 3.0 m plus a 150 mm addition from each external support in both long-term and short-term tests. Each slab was continuous on the inner support and roller was a supported at each end. The shrinkage of concrete was accounted for an age of 90 days where serviceability behavior of slabs was considered.

It was noted that at 98 days of drying, the shrinkage strains obtained in the specimens of fiber-reinforced concrete which contain quantities equal to 40 kg/m3 and normal concrete samples were similar. When steel fibers are used more than 60 kg/m3, this will lead to increase in the the slip load by about 42% while developed crack control considerably as the maximum crack width is frequently reduced by about 50%. There was no cracking occur due to the creep and shrinkage-strains in the mesh-reinforced or fiber-reinforced composite slabs under their dead load (self-weight) until 90 days of drying. Consequently, the tested slabs were exposed to increasing the load until final load which failed with it. The deflection was observed at the center and finished against the applied load was observed and the size of the cracks were attained for all slabs with various stages of load.

Redha et al, in 2017 [28] tested continuous bubbled deck slabs as part of nine various types of slabs. The test considerations involved the diameter of bubbles to thickness of slab (D/t) ratio (0.6 and 0.7), type of the concrete (RPC and NC), bubbles location (at all slab space, started at distance 2D and 3D from the center of slab) and solid slab. The test results displayed that the crack shape and the failure load in addition to the deflection at the failure load depend on all of the mentioned parameters.it is shown that by increase (D/t) ratio, eventually increasing the load by (6.49 and 9.58%) started at distance 2D and 3D, respectively for slabs with bubble, But in slabs with bubbles occupying all slab area, the ultimate load and the maximum deflection decreased by (6.63 to 9.47%) and (7.96 and 6.84%) for RPC and NC slabs, respectively. Also, the solid slab had higher ultimate load by about (5.28%) compared to bubble slab. It was found that by eliminating bubbles from the center of the slab at space 2D and 3D the final load increased by about (14.72 and 8.76%), respectively for slabs with (D/t = 0.6) compared to slabs with bubbles at all slab area, and for slabs with (D/t = 0.7) the ultimate load increased by (30.85 and 27.65%), for bubbles at distance 2D and 3D, respectively as shown in Figure (4).

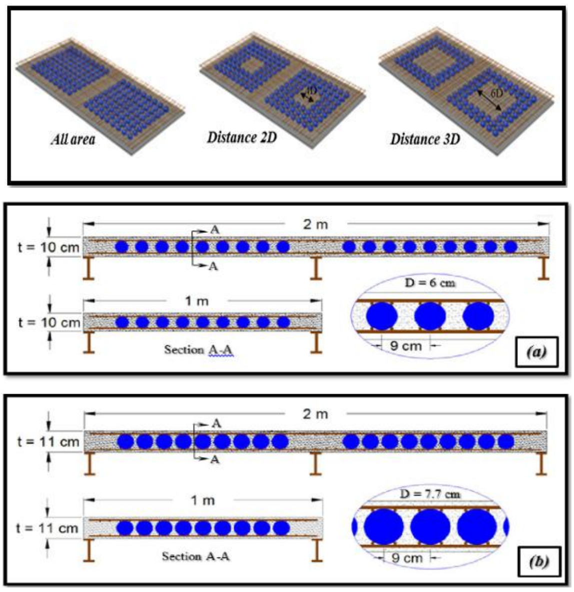

Figure 4. Schematic Representation of bubbled Slabs [28]

Therefore, the innovation policy links all the policies and strategies of the enterprise and determines the location of each function implemented by the enterprise within the overall business. The role of the innovation policy in the innovation management lies in the innovative activity regulation and management. The innovation policy seems to be a core – a key unit in the development of the strategies of the enterprise at all levels of functional units. The financial strategy is one of the key components in the development of a comprehensive innovation strategy of the enterprise.

CONCLUSION

1- Reactive powder concrete gives enhanced performance such as toughness and corrosion resistance.

2- For RPC shown that heat treatment in 90o C achieved larger values of splitting tensile strength from 25 to 35 MPa, and compressive strength from 120 to 180 MPa.

3- When the brass plated fibers are used in the mix of the RPC mixture, the compressive and flexural strength was found to be higher than RPC having fibers of different types.

4- The increase in end hooked fibers related to straight fibers which is added to RPC gives higher flexural strength by 8%.

5- The concrete can be made with compressive strength equal to 132MPa, flexural strength equal to 19.1MPa, dynamic modulus equal to 48.61GPa.

6- The addition of fibers didn't changed the first crack load of normal concrete slabs, but the load of cracking at flexural of normal concrete increases by about (25 and 32) % and the capacity at maximum load of normal concrete increases by (20 and 34) %with the a5ddition of fibers by volume of fraction of (0.32 and 0.48) %.

7- Interaction of the fiber matrix helps to improve the mechanical characteristics resulting from the institution of fibers, which differs from existing prototypes and combinations fabricated on the rule of mixtures.

8- The important effects of using RPC and MRPC on punching shear strength of slabs are obvious. The ultimate load at failure of RPC slabs was enlarged between (39.05-181.50) % over NSC slabs, and for MRPC slabs between (63.8-138.5) %. The ultimate strain of RPC and MRPC slabs presented that the increase in amount of fiber increases ultimate tensile strain between (15-99%), and decreases the ultimate compressive strain between (1.5-33.3) %.

9- The treatment in normal water at 20°C provides the compressive strength about (57-65) % at 3 days from the compressive strength of concrete of 28 days while about (75) % of 28 day compressive strength for 7 days. While the compressive strength in treatment with 80°C about (80-90) % of that of 28 day for 3 days, and at 7 days is about (93-97) % of that of 28 days.

10- The increases in steel fiber contents and silica fume lead to an increase the ultimate load and thus lead to increase in the deflection at failure load and curvature while more content of steel ratio may cause to greater load at failure and less content of both deflection at failure and curvature. Moreover, flexural toughness increased with the increase in fibers content and silica fume contents.

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