CHAPTER 3

AIM AND OBJECTIVES OF STUDY

Based on literature review conducted, the research areas of RPC are found to be focused on understanding of RPC as special material. Research has been carried out to study its mechanical properties when formulated under special conditions, its micro-structural analysis, and its potential areas of applications.

The aim and the objectives taken up in this research study, is presented further which are based on the gaps found in the research area of RPC.

3.1 GAPS IN RESEARCH AREA OF RPC

The literature review conducted has revealed some important research areas still to be explored in the area of RPC which has been alluded below.

i) The earlier studies on RPC have accentuated on assumed proportions of constituents and its effects on strengths due to the variation in their proportions. These studies have been carried out considering the special curing conditions suitable for precast industry. For the application of RPC related to in-situ conditions, the properties need to be determined under normal curing conditions and effect of variation in constituents on the properties under normal conditions need to be studied.

ii) Mix design of RPC is more complicated as it the coarse aggregates are excluded and constituents like super-plasticizer and supplementary cementitious materials like silica fume are included. In addition, a low w/c ratio to be maintained for desired workability makes the design process more complicated. There is a scantiness of the research done on modeling the compressive strength of RPC. Adopting trial mixes is one of the option for modelling the strength of RPC. Artificial Neural Network (ANN) technique can be used to predict the compressive strength of RPC based on concrete mix proportions.

iii) RPC being a separate class of concrete as compared to the conventional concrete, the relationship between compressive strength ($f_{ck}$) and Young’s modulus of elasticity ($E$) of conventional concrete specified in IS 456 (2000) may not hold good. Young’s modulus of elasticity of concrete is an important property to be evaluated as it relates directly to the structural behaviour of any element where it is used. Hence, $E$ for RPC needs to be
evaluated. Studies on compressive stress-strain relationship need to be carried out to establish the relationship between $f_{ck}$ and $E$ of RPC.

iv) The majority of literature brings out studies on the compressive strength of RPC under controlled laboratory conditions. In-situ application of RPC such as application in beam-column joints will expose it to different environment (climatic) conditions depending on the place where it is used. The effect of various combinations of temperature and humidity conditions on the gain of compressive strength of the RPC needs to be explored. During the period of curing, the exclusive effect of variation in humidity/temperature on the compressive strength of RPC also needs to be studied.

v) Considering the research work carried out on the applications of RPC in structural engineering, it has been observed that its use is more focussed in the construction of bridges, pre-stressed members and components subjected to blast loading. However these studies on RPC are conducted with fiber content and applicable to precast industry. Hardly any studies in the literature mention the use of RPC in structural components in building. One of the application of RPC in building can be its use in the beam-column joint of RC frame structure. One of the major failure pattern observed in frame structures is in beam-column joints which influences the response of entire frame. This failure may be due to any non-uniform settlement in foundation, severe ground shaking, and influential wind forces. The failure in joints is brittle shear failure which is undesirable. It is necessary to enhance the performance of these beam-column joints. Studies are required to be carried out using RPC in the beam-column joint and its interfacial behaviour with conventional concrete needs to be studied.

The above gaps mentioned are focussed with reference to the application of RPC in beam-column joint. The objectives of this research programme are defined in next section and are directed to explore the gaps mentioned above and explore the prospect of application of RPC in beam-column joint.

### 3.2 AIM AND OBJECTIVES

Characterization of RPC and the studies on behaviour of beam column joints using RPC will find its application in enhancing the overall behaviour of structural members maintaining balance between high strength and economy. Based on the above hypothesis and based on gaps highlighted above, the aim and objectives for this research study have been further defined as follows.
Aim:

The purpose of the study is to characterize reactive powder concrete and arrive at a mix design for its suitability for enhanced performance of the beam-column joints in RC frame.

Objectives:

i. To study properties of fresh and hardened RPC through mix design process.

ii. To establish the relation between the compressive strength ($f_{ck}$) and the Young’s modulus of elasticity (E) of RPC.

iii. To study the effect of humidity and temperature on compressive strength of RPC

iv. To study the bond behaviour between the conventional fresh concrete and RPC.

v. Scale model experimentation of beam column joint behaviour using RPC and its validation by analyzing beam column joints by using finite element models.

3.3 SCOPE OF THE WORK

Based on the objectives framed for achieving the aim of this research study, the areas of work have been identified and the scope of work is defined in each case as follows.

3.3.1 Properties of Fresh and Hardened RPC

Experiments are conducted to study the properties of fresh and hardened RPC. Trial mixes are developed by varying the proportions of ingredients viz. cement (c), silica fume (sf), quartz sand (qs) along with variation in water/cement ratio (w/c). The compressive strength is found out for 112 proportions formed by the combinations of proportions of the constituents. The workability in each mix is maintained to have a flow of 110-130 mm. Study of the effect of the variations of constituents on compressive strength is studied.

Based on the exhaustive data of compressive strength of 112 proportions, ANN model is established for prediction of the compressive strength of RPC for any particular proportion. The model is built on the input of proportions of constituents; viz. silica fume/ cement (sf/c) ratio, quartz sand/cement (qs/c) ratio, and water/cement (w/c) ratio.

Workability test on RPC is carried out using the flow table. The constituents effecting workability are silica fume content, w/c ratio and dosage of super plasticiser. The variation in sf/c ratio, w/c ratio and dosage of super-plasticizer is made to obtain 63 proportions and studies for workability are conducted on the mixes with these 63 proportions.
The size and shape effect on the compressive strength of RPC is studied by casting specimens of 70.7 mm size cube, 100 mm size cube, 150 mm size cube, and 150 mm diameter cylinder. Apart from the compressive strength, other mechanical properties of RPC such as strength in flexure, shear, and direct tension are determined. In this part of the experiment, the study of the effect of silica fume on these properties is studied.

3.3.2 Young’s Modulus of Elasticity of RPC

Since this research is focussed on application of RPC in beam-column joint, the load deflection characteristics of beam-column joint using RPC need to be studied. In this context, E for RPC becomes the succeeding important property to be studied after its compressive strength. Experimental work to obtain the uniaxial compressive stress-strain curve for eight mixes is carried out. The variation in content of silica fume is made to obtain different mixes. The Young’s modulus of elasticity (E) for each mix is found out and it is related to the compressive strength ($f_{ck}$) of the mix thereby developing the relation between the compressive strength ($f_{ck}$) of RPC and Young’s modulus of elasticity (E).

3.3.3 Effect of Humidity and Temperature on Compressive Strength of RPC

Experimentation process to observe the effects of humidity and temperature on gain in compressive strength consisted of air curing the specimens in four varied climatic conditions. All the RPC specimens are subjected to specified humidity and temperature conditions in a humidity chamber. The specimens are also field cured (water cured at room temperature) and comparison of all specimens is made with specimens cured under standard laboratory conditions.

Also, the exclusive effect due change in humidity conditions (keeping temperature constant) and the exclusive effect due to change in temperature of water during curing are studied and inferences are made.

Eight different mix proportions were considered and for each temperature and humidity condition, the specimens were cured for 7, 14 and 28 days. A total of 768 samples were cast.

3.3.4 Bond Behaviour between the Conventional Concrete and RPC.

With reference to focussing the use of RPC in the beam-column joint along with the conventional concrete, study of interfacial bond strength of RPC with conventional concrete and steel becomes inevitable. Slant shear test and bi-surface shear test have been adopted to conduct studies on bond between RPC and conventional concrete. The bond between RPC and
reinforcing bars is conducted using pull-out test. The effect of variation of silica fume in RPC on its bond strength is studied for all the three tests considering eight proportions.

### 3.3.5 Application of RPC in Beam-Column Joint.

Scale model experimentation for beam-column joint behaviour is carried out. Half scaled models of beam-column joint are cast and tested for a static load for four different cases mentioned below.

a) Normal beam-column joint (NBCJ); Entire model cast with normal conventional concrete.

b) Full RPC beam-column joint (FRBCJ); Entire model cast with RPC.

c) Vertical RPC & normal concrete beam-column joint (VRNBCJ); model cast with RPC in the joint portion along with normal concrete, and the interfacial plane between the two concretes is kept vertical in beam and column.

d) Inclined RPC & normal concrete beam-column joint (IRNBCJ); model cast with RPC in the joint portion along with conventional concrete, and the interfacial plane between the two concretes kept inclined at 30° with vertical in beam portion.

Load versus deflection curves are acquired, crack patterns are observed and inferences are made.

The experimental results are validated by analysing the beam-column joints subjected to quasi-static monotonic loading by using finite element analysis models.

Further analysis for cyclic load is performed. The performance of the joints are studied with respect to evaluation parameters like peak loads, stresses, energy dissipation and stiffness.