3.7.1.1: Total number of Collaborative activities per year for research/ faculty exchange/ student exchange/ internship/ on –the-job training/ project work

2017-18				
Sl. No.	**Name of the participant**	**Duration**	**Nature of the activity**	**Page Number**
80	R.Uday Kumar, P.Ravinder Reddy, A.V.SitaRamaraju	4 months	Research Publication	05
81	P. Radha Krishna Prasad , P. Ravinder Reddy, K. Eshwar Prasad	4 months	Research Publication	06
82	L Siva Rama Krishna, B Karthik Anand, Ritesh Rajan, T Hima Bindu, P.Ravinder Reddy	4 months	Research Publication	07
83	T. Hima Bindu , L. Siva Ramakrishna , P. Ravinder Reddy , M.Tejdeep , B. Karthik Anand	4 months	Research Publication	08
84	Syed Naveed Ahmed, Dr. P Ravinder Reddy, Dr Sri Ram Venkatesh	4 months	Research Publication	09
85	S.V.Prasad , Dr.P. Laxminarayana , Dr.P. Ravinder Reddy	4 months	Research Publication	10
86	Md. Aleem Pasha, Dr. P. Ravinder Reddy, Dr.P.Laxminarayana	4 months	Research Publication	11
87	P. Ashok Kumar, P. Ravinder Reddy, AVSSKS. Gupta	4 Months	Research Publication	12
88	Pavan Kumar Thimmaraju, Krishnaiah Arakanti, G. Chandra Mohan Reddy	4 Months	Research Publication	13
89	N.Janardhan, M. Ravi Chandra, M.V.S.Murali Krishna	4 Months	Research Publication	14
90	D.S.Madhuri, M.Ravi Chandra, M.V.S. Murali Krishna	4 Months	Research Publication	15
91	R.Chanakya, D.Srikanth, M.Ravi Chnadra, M.V.S. Murali Krishna	4 Months	Research Publication	16
92	D.Srikanth, M.V.S. Murali Krishna, P.Usha Sri, M.Ravi Chandra	4 Months	Research Publication	17
93	D.S.Madhuri, M.Ravi Chandra, M.V.S. Murali Krishna	4 Months	Research Publication	18
94	K. Vamsi Krishna, G Ravi Kiran Sastry, M.V.S. Murali Krishna	4 Months	Research Publication	19
95	K.V.Krishna, G.R.K.Sastry and M.V.S.M.Krishna	4 Months	Research Publication	20
96	Ch.Indira Priyadarsini, M.V.S.Murali Krishna, P.Usha Sri	4 Months	Research Publication	21
97	T.Pavan kumar, P.Prabhakar Reddy	4 Months	Research Publication	22
98	Pavan kumar.T, P. Prabhakar reddy	4 Months	Research Publication	23
99	Pavan kumar.T, P. Prabhakar reddy	4 Months	Research Publication	24
100	Gopal, Dr. L. Suresh Kumar, V.	4 Months	Research Publication	25

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	Jaipal Reddy, M. Umamaheswara Rao, K. Pavan Kumar			
101	Satyanarayana A, M. Krishna, A. Chandrakanth, Pradyumna R	4 Months	Research Publication	26
102	D.Ravi, Samson Yohennes, Habtamu Mitiku Feyissa, B.Koteswara rao	4 Months	Research Publication	27
103	Maraboina Raju, Munish Kumar Gupta, Neeraj Bhanot, Vishal S.Sharma	4 Months	Research Publication	28
104	Jagannath Saragadam-160115737050	14-05-2018 to 23-06-2018	Internship	30
105	Khushbu Jindal-160116737010	20-06-2018 to 17-08-2018	Internship	31
106	Pranavi Mankala-160116737020	01-05-2018 to 01-06-2018	Internship	32
107	Gudur Sona-160116737023	28-05-2018 to 27-06-2018	Internship	33
108	V. Gouthami-160116737002	01-05-2018 to 15-06-2018	Internship	34
109	Lakshmi Harika-160116737013	01-05-2018 to 01-06-2018	Internship	35
110	Neha Dinesh Prabhu-160117737011	04-11-2017 to 04-12-2017	Internship	36
111	C. Spandana-160116737026	01-06-2018 to 29-06-2018	Internship	37
112	P.Durga Prasad-160116737089	04-06-2018 to 19-06-2018	Internship	38
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114	M. Anjani	40 DAYS	Separation of water and etahnol by progressive freeze concentration	40
115	M. Srilekha	15 DAYS	Condenser designing	41
116	K. B. Mahalakshmi	1 MONTH	Zirconium oxide production and experimental study on filtration and evaporation of sodium nitrate along with evaporator design process	42
117	Dr K Prasad Babu	01 year	Research Publication	43
118	Dr K Prasad Babu	01 year	Research Publication	48
119	A.ANUSHA	30	Internship	64
120	GUNJA LATHA	30	Internship	
121	ROKULAMAN VIJAYALAXMI	30	Internship	66

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124	A.DIVYA TEJA	35	Internship	69
125	AVANTHI BINDLA	21	Internship	70
126	S.Monika	30	Internship	71
127	S.DIVYA SRI	30	Internship	72
128	S.UTKARSHA	14	Internship	73
129	KASIM AISHWARYA	30	Internship	75
130	C.A. SANJANA REDDY	30	Internship	76
131	Preethi Thota	35	Internship	77
132	Sai nikhil	35	Internship	78
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134	Ch.Varshik	35	Internship	80
135	B.Poojitha	30	Internship	81
136	B.Nikhil	10	Internship	82
137	KEESARA ARAVIND	30	Internship	83
138	B.DIVYA	30	Internship	84
139	T.VISHWA TEJA	30	Internship	85
140	B.UMA MAHESH	30	Internship	87
141	A.SUKUMARAN ADARSH	21	Internship	89
142	A.SHIVA KRISHNA	30	Internship	90
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146	T.LAKSHMI DEEPIKA	30	Internship	97
147	BATTULA SAI CHARAN REDDY	14	Internship	98
148	B.SAI CHARAN	21	Internship	99
149	K.RONITH RAJ	21	Internship	100
150	R,ROHITH	30	Internship	101
151	P.NIRNAY REDDY	10	Internship	102
152	M.NIKHIL	10	Internship	103
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160	CHAVALI TULASI KISHORE REDDY	14	Internship	111
161	BOORLA PAVAN KUMAR	30	Internship	112

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165	Touseeq Anwar Wasif, A. Vimala & M Koti Reddy	1 Year	Reserach Paper	146
166	N Srikanth, Dr. N. R. Dakshina Murthy & M.V. Seshagiri Rao	1 Year	Reserach Paper	159
167	Srinivas Vasam, K. Jaganaadharao, M. V. Seshagirirao	1 Year	Reserach Paper	168

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Role of Viscosity in Hydro-forming Process

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ABSTRACT

Hydro forming is new development in the manufacturing of various products in the field of engineering. In the manufacturing area one of the hydro forming process is Hydro forming deep drawing. Hydro forming deep drawing is one of sheet metal forming process to produce seamless shells, cups and boxes of various shapes. In this forming process, an additional element such as fluid pressure is to be contributes positively in several ways. In hydro forming deep drawing process, applying the hydraulic pressure on blank periphery in radial direction. It is obtained through the punch movement within the fluid chamber, which is provided in punch and die chambers. These two chambers are connected with the bypass path and it is provided in the die. During the process punch movement within the fluid chamber the pressure is generated in fluid and it is directed through the bypass path to blank periphery, the fluid film is created on the upper and lower surfaces of the blank and subsequently reduces frictional resistance and is to reduce tensile stresses acting on the wall of the semi drawn blank. The blank is taking at centre place in between blank holder and die surface with supporting of high pressurized viscous fluid. The radial stresses are produced in the blank in radial direction due to punch force applied on it. The shear stresses acted by viscous fluid on the both sides of blank, so apply viscosity phenomenon to this analysis. Due to the viscosity of fluid the shears stresses and shear forces acted on blank during drawing process. This viscosity used for determination of radial, hoop and drawing stresses in this process. The viscosity is maintained major role in hydro forming process. The blank holder pressure is controlled by the radial pressure of fluid and these are equal for uniform deformation of blank to obtained required shape and also elimination of failure of blank in deformation. Newton's law of viscosity is applied for this process for evaluation of stresses. The radial stresses are determined in terms of viscosity of castor oil, shear stresses, blank geometry and process parameters for magnesium alloy. The study on these stresses in castor oil medium with consideration of its viscosity.

Selection and peer-review under responsibility of Conference Committee Members of 5th International Conference of Materials Processing and Characterization (ICMPC 2016).

Keywords: Hydro forming, Radial stress, Shear stress, Deep drawing process, Viscosity

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EFFECT OF WELDING PARAMETERS ON MECHANICAL PROPERTIES OF FRICTION STIR WELDED JOINTS OF AA6082 AND AA6061 ALUMINIUM ALLOYS

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ABSTRACT

The need of the hour in aerospace and military structures is the joints between dissimilar aluminium alloys. Friction stir welding (FSW) is a novel solid state joining technology especially developed for joining low melting temperature alloys like aluminium and magnesium. In this present investigation, AA6082 Aluminium alloy is friction stir welded with AA6061 Aluminium alloy for different combination of tool rotation speed, tool feed and tool tilt angle. A cylindrical tool with a square frustum probe is employed for friction stir welding. For each of the three factors rotational speed, tool feed and tool tilt angle two levels are selected. Eight experiments are designed on full factorial concept and FSW carried out for 8 runs. The tensile properties and microhardness were measured by UTM and Vickers hardness tester respectively. Using analysis of variance (ANOVA) optimum parameters are obtained and presented.

Key words: Friction stir welding, Dissimilar alloys, AA6082, AA6061, ANOVA.

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1. INTRODUCTION

Recent trend in the automotive world has been transition from conventional materials to light materials like Aluminium[1]. Due to the demands for a lower environmental impact through improved fuel efficiency, weight reduction and load capacity Aluminium is being used more widely in the auto industry, aerospace and marine structures [2] because of its light weight. Modern structural concepts demand reductions in both the weight as well as the cost of production. Fabrication of Aluminium alloys by riveting results in stress concentration and

FINITE ELEMENT ANALYSIS OF A FRACTURED MANDIBLE FIXED WITH MICRO PLATES

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Abstract:

It is observed that most of facial injuries occur due to accidents like falling from a height, assaults, different sport injuries, gunshot wounds and other traumatic injuries. These cases have been considered as challenging task for medical treatments. They are treated by Oral and Maxillofacial surgeon. For this type of injuries, a plating system is used, which is inserted into the affected victim's mandible and operated to the fractured mandible. This process is known as Osteosynthesis. The aim of this research work is to do Finite Element Analysis across the fracture line of a mandible fixed with conventional and locking micro plate. The stability of two types of plating systems such as conventional and locking type are analyzed using finite element analysis. Thus, the operated micro plates should withstand the forces acting on it. Plating system purpose is to regenerate and reconstruct the mandible to work naturally.

Keywords: 3D modeling, Micro Plating System, Osteosynthesis, Mandible, Finite Element Analysis

1. Introduction

The largest and strongest bone of the face, which serves for the movement of the lower teeth, is known as a mandible. It has a curved portion, body, and two perpendicular features called as the ramus, which joins with the ends of the body nearly at right angles. Mandible fractures (Lovald .T, 2006) are among the most common bone injuries in facial part. Treatment for mandible fractures (Gandhi and Haranal, 2012) has made significant advances over the years due to improved understanding of biomechanics principles, advances in bio materials and scientifically based research of treatment outcomes. However plating techniques involve rigid fixations (Oguz *et al.,* 2009) and incorporate good results in patient's case.

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Three Dimensional Modeling and Finite Element Analysis of Conventional Type Miniplates Fixed at Mandibular Fractures

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Abstract:-Mandibular fractures mostly consist of the traumatic injuries occurring at the mandible, treating these fractures by Oral and Maxillofacial surgeons is one of the most challenging tasks for them. The aim of this paper is to do Finite Element Analysis (FEA) on the conventional type miniplate and screws which are fixed to join fracture occurring at the symphysis (mid-line) area of the mandibular bone subjected to uniform loading. The Computer Tomography (CT) scanned images of a patient are collected in Digital Imaging and Communications in Medicine (DICOM) format. These images are then imported into image processing software MIMICS to develop the 3D surface model of the mandible and importinto the 3-Matic software for modifying the surface model and then finally saved in .STL file format. The saved .STL file format is imported into Solidworks software to develop 3D CAD model consisting assembly of the mandible, conventional type of miniplate and screws.The 3D CAD model of the assembled file was imported into ANSYS workbench and analyzed by applying uniformly distributed load (UDL) on the teeth area of mandible. The input given for Finite Element Analysis was the material properties of the cortical bone of the mandible andfor miniplates and screws the material properties of titanium alloy Ti-6Al-4V ELI (Grade 5) of the ASTM standard F136. In this paper, five different cases were considered and analyzed under static structural loading conditions by applying UDL.

A Study of the Secondary Flow in Aircraft Engine Compressor Disks using Computational Fluid Dynamics

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Abstract

The compressor disks of an aircraft engine which operate at very high rotational speeds are exposed to significant temperature gradients. These temperature gradients induce thermal stresses into the rotating disks which along with the existing dynamic stresses significantly reduce their useful field life. Hence it becomes essential to reduce the disk temperature gradients by utilizing a certain percentage of the compressor core flow known as the secondary flow for either heating or cooling these rotating parts. But this extraction of the compressor core flow results in a higher engine fuel burn for a given engine thrust. Hence the need arises for a better utilization of the secondary flow to effectively reduce the temperature gradients of the rotating compressor disks. As the secondary flow thermal phenomenon inside the rotating compressor disk cavities is very complex and due to it's direct impact on the life expectancy of the disks it becomes critical to understand it's thermo-fluid behaviour by the effective use of available Computational Fluid Dynamic tools. In the current study the secondary flow through the compressor disk cavities is simulated using Computational Fluid Dynamics (CFD) and the results are analysed and reported. The analysis of these results help in a better understanding of the distribution of the flow and the variations of the thermal fluid parameters across the secondary flow system. These results are also later used as thermal boundary conditions in the Finite Element model (FEM) to study the impact of various engine design parameters on the disk temperature gradients after being validated by the experimental results. The findings from this computer aided investigation offers support in make design improvements aimed at lowering the disk temperature gradients and enhancing their useful field life

Keywords: Compressor Secondary Flow, Computational Fluid Dynamics, Aircraft Engine, Compressor Disks, Thermo-fluid analysis.

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Influence of Tool Coatings on Distortion of 2014A T651 Aluminum Alloy during Machining

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ABSTRACT: This paper investigates the influence of coated and uncoated H.S.S and Carbide endmills on machining induced distortion in milling thin-wall, thin-floor components. The endmills are coated with Titanium Nitride (TiN), Titanium Aluminum Nitride (TiAlN), and Diamond like Carbon (DLC).The effect of each of the coated H.S.S and carbide end mills is studied by calculating residual stresses using indentation method. The present article also suggests the optimum coating and the tool material for minimizing distortion. Results show that coatings on the tool has significant effect on the residual stress distribution and distortion of components. It is also observed that machining induced stresses by using DLC coating are minimum leading to minimum distortion.

KEYWORDS: Machining, Distortion, Residual stress, Indentation Method, Aluminum Alloy, TiN, TiAlN, DLC, H.S.S, Carbide.

I. INTRODUCTION

Dimensional and form accuracy of machined component in aerospace industry is one of the challenging tasks for manufacturer. In the aerospace industry, machining process is widely used for fabrication of monolithic component that contains a thin-walled structure. Stresses and part distortion have a major cost impact in many machining applications since they can affect scrap rates and processing times. For example, in Avionic monolithic components they may produce distortions which hamper assembly operations. Stresses in machined parts could be either bulk residual stresses from primary processes such as rolling or forging or the stresses induced by the machining process, which are a result from differential plastic deformation and surface temperature gradients [1]. During machining, the cutting forces create thermal and mechanical stresses causing deflection to the thin-wall section, leading to dimensional form errors. Most of the existing research for machining thin-wall component and its correlation to distortion, concentrated on the process parameters (speed, feed, depth of cut, width of cut, material removal rate, volume of material removal, type of cutting fluid, tool path layout, etc) [2,3,4,5] and tool parameters (axial and radial rake angles, helix angle, gash angle, dish angle and clearance angles)[6,7,8,9,10]. The effects of coatings on the tool are often neglected. Coating on the cutting tool has a direct influence on the cutting performance and stress induced and hence should not be neglected in the machining consideration.

High Speed Steel is a high carbon tool steel, containing a large dose of tungsten. A typical HSS composition is 18% tungsten, 4% Chromium, 1% Vanadium, 0.7% carbon and the rest, Iron. HSS tools have a hardness of 62-64 Rc. The addition of 5 to 8% cobalt to HSS imparts higher strength and wear resistance. The advantage of HSS over carbide is its strength to withstand cutting forces and the low cost of the tools. From the tool life point of view, HSS performs very well at intermittent cutting applications. But the greatest limitation of HSS is that its usable cutting speed range is far lower when compared to Carbide. For enhancement in productivity, carbide tools are generally preferred to H.S.S tools in machining. Carbides have high hardness over a wide range of temperatures, high thermal conductivity, high Young's

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Finite Element Analysis of SiC Reinforced and Unreinforced Friction Stir Welding of Mg Alloy AZ31B

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Abstract
This paper explains the numerical analysis of Silicon carbide reinforced of 10%, 15%, 25%, and 30% by volume and unreinforced friction stir welding processes of magnesium alloy AZ31B. In this paper the heat input and temperature distribution during friction stir welding is investigated. The temperatures at different positions in the nugget zone were recorded with the temperature gun during welding under various welding conditions such as percentage of volume proportion of reinforcement. The finite element model was developed for different volume proportions of reinforcement and simulated using finite element method program (ANSYS).Validated the simulation results with experimental results.

Keywords: Friction stir welding, magnesium alloy AZ31B. Silicon carbide, Numerical, analysis, Temperature distribution

1. Introduction

Friction stir welding (FSW) is a novel solid-state joining process that may have significant advantages compared to the fusion processes as follow: Joining of conventionally non-fusion weldable alloys, reduced distortion and improved mechanical properties of weldable alloys joints due to the pure solid-state joining of metals. In a typical FSW, a rotating cylindrical pin tool is forced to plunge into the plates to be welded and moved along their contact line. During the welding, heat is generated by contact friction between the tool and workpiece softens the material. Since no melting occurs during FSW, the process is performed at much lower temperatures than conventional welding techniques. Because of the highest temperature is lower than the melting temperature of the material, FSW yields fine microstructure [1]. Chen and Kovacevic studied on the finite element analysis of the thermal history and thermo mechanical process in the butt-welding of aluminum alloy 6061- T6 [2]. Nandan et al. modeled three-dimensional visco plastic flow and temperature field during FSW of 304 austenitic stainless steel mathematically [3]. Buffa et al. proposed a 3D FEM model for the FSW process that is thermo-mechanically coupled and with rigid-viscoplastic material behavior [4]. Zhang et al. developed solid mechanics based finite element models and computational procedures to study the flow patterns and the residual stresses in FSW. They concluded that with the increase of the translational velocity, the maximum longitudinal residual stress can be increased [5]. Chao et al. formulated the heat transfer of the FSW process into two boundary value problems (BVP)-a steady state BVP for the tool and a transient BVP for the workpiece [6]. Song and Kovacevic presented a three-dimensional heat transfer model for FSW. They introduced a moving coordinate to reduce the difficulty of modeling the moving tool and considered heat input from the tool shoulder and the tool pin in their model. They concluded that preheat to the workpiece is beneficial to FSW [7]. Hamilton et al. developed a thermal model of FSW that utilizes a new slip factor based on the energy per unit length of weld. The slip factor was derived from an empirical, linear relationship observed between the ratio of the maximum welding temperature to the solidus temperature and the welding energy [8]. Soundararajan et al. developed a thermo-mechanical model with both tool and workpiece using mechanical loading with thermal stress to predict the effective stress development at the bottom of workpiece with uniform boundary conditions. [9]. Rajamanickam et al. investigated the effect of process parameters such

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CHARACTERIZATION OF DELAMINATION BEHAVIOR OF CARBON/EPOXY LAMINATES USING DOUBLE CANTILEVER BEAM (DCB) SPECIMENS

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ABSTRACT

Interlaminar fracture toughness plays an important role to predict delamination growth and strength of the overall composite structure. The influence of ply orientation on the Mode I interlaminar fracture behavior of the carbon/epoxy composite laminate in quasi-static loading was investigated using the double cantilever beam (DCB) specimen. Tests were carried out on four different 16-ply specimens to measure the interlaminar fracture toughness in terms of critical strain energy release rate, G_{Ic}. Experimental results showed that the Mode I interlaminar fracture toughness at the crack initiation and propagation increases with adjacent ply orientations. The plateau value of R-curve increases with the adjacent ply angles which was correlated to fiber bridging. Further, preliminary results in terms of G_{Ic} initiation values showed good agreement between the finite element analysis (FEA) and experimental results.

Keywords: Carbon/Epoxy, Delamination, Fiber Bridging, Interlaminar Fracture Toughness, Quasi-Static Condition

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STUDY OF INFLUENCE OF TOOL GEOMETRY ON MATERIAL FLOW PATTERN IN FRICTION STIR WELDING PROCESS USING FINITE ELEMENT SIMULATION

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ABSTRACT

Material flow pattern studies are conducted during the friction stir welding process, to evaluate the influence of tool geometry on the flow characteristics. This is done considering the material movement in the case of friction stir welding is happening by material flow around the rotating tool and is considered as a viscous flow exhibiting laminar flow characteristics exhibiting non-Newtonian properties. Velocity field and the viscosity fields are considered as the criteria to differentiate the various weld zone viz. Weld nugget zone, HAZ & TMAZ. To compare the influence of tool geometry on the material flow behavior various tool pin profiles are considered and the resulting velocity distributions are compared. the results obtained revealed the tool pin geometry has a considerable effect on the weld nugget zone.

KEYWORDS: Friction Stir Welding, Material Flow, Fem, Velocity field & Tool Geometry

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Original Article

INTRODUCTION

Friction Stir welding process has been a significant metal joining process since its invention by The Welding Institute(TWI) in 1991[1].Friction Stir welding process is a joining process which employs a tool which rotates and travels along the joining surfaces which are clamped together. The tool is non-consumable and many types of tool profiles are employed for the welding purpose. Tool geometry is defined by the diameter of the shoulder, diameter of the pin, shape of the pin and the pin length. The pin length is usually shorter than then the thickness of the plates to be welded. The pin is penetrated into the work pieces and the tool rotates and transverses along the centerline. The interaction between the work piece and the tool results in friction generating heat which in turn creates plastic deformation and the flow of the work piece material takes place in plasticized state as the tool traverses forward [2].the process is illustrated in the Figure 1.

The material flow in friction stir welding is complex in nature and mainly depends on the tool geometry, process parameters such as tool rotation speed, welding speed, tool tilt angle, axial force and properties of the material to be welded. The weld formation depends on the material flow behaviour of the materials, to be welded.

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Experimental Investigations on Di Diesel Engine with High Grade Insulated Combustion Chamber with Varied Injection Pressure

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Abstract -- To evaluate the performance of diesel engine with high grade low heat rejection combustion chamber which consisting of air gap insulated piston with 3 mm air gap, with superni (an alloy of nickel) crown, air gap insulated liner with superni insert and ceramic coated cylinder head with neat diesel with varied injection pressure experiments were carried out. Performance parameters brake thermal efficiency, exhaust gas temperature, coolant load, volumetric efficiency and sound levels were determined at different values of brake mean effective pressure (BMEP) of the LHR–3 combustion chamber and compared with neat diesel operation on conventional engine (CE) at similar operating conditions. It is also found that Engine with LHR–3 combustion chamber with neat diesel operation showed deteriorated performance at manufacturer's recommended injection timing of 27o bTDC. The Injection pressure changed from 190bar to 270bar with an increment of 40bar.

Index Terms: Conservation of diesel, conventional engine, LHR combustion chamber, Performance

I. INTRODUCTION

The advancement of civilization causes increase of vehicle population at speed rate and increase in usage of diesel fuel in transport and agriculture sector leading to depletion of diesel fuels. Increase in prices of diesel fuel in International market has become another burden on economic sector of India. The conservation of diesel fuel has become inevitable for the engine, users and researchers involved in the combustion research. [Matthias Lamping et al, 2008].

Dr. Diesel had made a remarkable invention of the diesel engine, as their excellent fuel efficiency and durability, became popular power plant for automotive industry. It has got global acceptance as it is used in agricultural sector, industrial applications and construction equipment and marine propulsion. [Cummins et al, 1993; Avinash Kumar Agarwal et al, 2013].

Low Heat combustion chamber concept is to reduce coolant losses by incorporating the thermal barriers in the path of heat flow to the coolant that make the gaining thermal efficiency. There are different methods to achieve this by coating the cylinder head with ceramic and maintaining the air gaps in piston and in the liner. Pistons and liners are made with low thermal conductivity materials like superni(an alloy of nickel) , cast iron and steel.

Low Heat combustion(LHR) chamber were classified as low grade Low Heat Rejection Combustion chamber which is engine with ceramic coated cylinder head, medium grade Low Heat Rejection Engine which is having air gap in piston and air gap in the liner and high grade Low Heat Rejection combustion chamber which is combined arrangement of low grade and high grade.

Experiments were already carried out with engine with low grade Low Heat Rejection combustion chamber diesel engine[Paralak et al, 2005; Ekrem et al, 2006; Ciniviz et al, 2008; Janardhan et al, 2014; Janardhan et al, 2015]. They revealed that brake specific fuel consumption decreased by 3-4% in comparison with conventional engine. Tests were carried out by keeping the air gap in piston [Parker et al, 1987]. However, they fixed up the crown with bolted joint, which had become a failure concept as it was not sealed air completely in the gap. It was become a successful by screwing the crown to the piston, by keeping a gasket, made of superni in between these two parts [Rammohan et al, 1999; Janardhan et al, 2015].

Experiments were conducted on high grade Low Heat Rejection engine with injection pressure at recommended injection timing to study the pollution levels of smoke and NOx levels. They came to know that drastically increased in the NOx levels. It was known clearly from literature survey that hot combustion chamber is suitable for high viscous vegetable oils.

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INFLUENCE OF INJECTION PRESSURE ON PERFORMANCE PARAMETERS OF SEMI ADIABATIC DIESEL ENGINE WITH CRUDE VEGETABLE OIL WITH MAGNETIC INDUCTION

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ABSTRACT: Increase of injector opening pressure has a significance effect on performance and formation of pollutants inside the direct injection diesel engine combustion. Compression ignition (CI) engines are used to move major portion of the world's goods, power much of the world's equipment, and generate electricity more economically than any other device in their size range. Increasing industrialization of developing countries is resulting in increased demand for diesel worldwide. Substitution of this demand with straight vegetable oils (SVOs) is comparatively environmentally benign compared to diesel and biodiesel. However, drawbacks associated with crude vegetable oil of high viscosity and low volatility, which cause combustion problems, call for low heat rejection (LHR) engine or semi adiabatic diesel engine with its significant characteristics of maximum heat release and ability to handle the low calorific value fuel. LHR engine consisted of ceramic coated cylinder head. A hydrocarbon fuel was polarized by exposure to external force such as magnetism. The result of which is of course, more complete and rapid burning of the hydrocarbon fuel. Investigations were carried out to determine performance parameters of brake thermal efficiency, brake specific energy consumption, exhaust gas temperature, coolant load and volumetric efficiency with conventional engine (CE) and LHR engine with and without magnetic induction with vegetable oil operation with varied injector opening pressure. With vegetable oil with LHR engine with magnetic induction improved performance, when compared with CE.

Keywords: [Vegetable oils, Low heat rejection, Ceramic coating, Performance parameters, Injector opening pressure]

1. INTRODUCTION

Fossil fuels are limited resources; hence, search for renewable fuels is becoming more and more prominent for ensuring energy security and environmental protection. It has been found that the vegetable oils are promising substitute for diesel fuel, because of their properties are comparable to those of diesel fuel. They are renewable and can be easily produced. When Rudolph Diesel, first invented the diesel engine, about a century ago, he demonstrated the principle by employing peanut oil. He hinted that vegetable oil would be the future fuel in diesel engine [1]. Several researchers experimented the use of vegetable oils as fuel on conventional engines (CE) and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character. It caused the problems of piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions [1–5]. Increased injector opening pressure may also result in efficient combustion in

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Research Article

Experimental Investigations on Low Grade Low Heat Rejection Diesel Engine with Crude Cottonseed Oil Blended with Butanol

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Abstract

In the scenario of fast depletion of fossil fuels, search for alternative fuels has become pertinent. Alcohols and vegetable oils are important substitutes for diesel fuel as they are renewable in nature. However, drawbacks of alcohols (low cetane number and low energy content) and vegetable oils (high viscosity and low volatile in nature) cause combustion problems in diesel engine and hence call for low heat rejection (LHR) engine, which can burn low calorific value fuel and give high heat release rate. They are many methods to induct alcohol in diesel engine out of which blending of alcohol with vegetable oil is simple technique. Neat vegetable oils produce high particulate emissions in diesel engine as they contain fatty acids. Neat alcohol causes combustion problems as it has low cetane number. Hence blending of alcohol with vegetable oils is a promising technique. Butanol has higher calorific value than ethanol and methanol. Hence use of butanol is finding favor in diesel engine. Investigations were carried out to evaluate the performance parameters of a low grade low heat rejection (LHR) diesel engine or LHR–1 engine consisting of ceramic coated cylinder head with crude cottonseed oil blended with butanol with varied injector opening pressure. Performance parameters of brake thermal efficiency (BTE), exhaust gas temperature (EGT), coolant load and volumetric efficiency (VE) were determined at various values of brake mean effective pressure (BMEP). Conventional engine (CE) showed deteriorated performance, while LHR engine showed compatible performance with crude cottonseed oil. (CSO) operation when compared with neat diesel operation at recommended injection timing and pressure. The performance of both version of the engine improved with vegetable oil blended with butanol with varied injector opening pressure.

Keywords: *Vegetable oil, Injector opening pressure, LHR engine, Classification, Fuel Performance.*

1. Introduction

The civilization of a particular country has come to be measured on the basis of the number of automotive vehicles being used by the public of the country. The tremendous rate at which population explosion is taking place imposes expansion of the cities to larger areas and common man is forced, these days to travel long distances even for their routine works. This in turn is causing an increase in vehicle population at an alarm rate thus bringing in pressure in Government to spend huge foreign currency for importing crude petroleum to meet the fuel needs of the automotive vehicles. The large amount of pollutants emitting out from the exhaust of the automotive vehicles run on fossil fuels is also increasing as this is proportional to number of vehicles. In view of heavy consumption of diesel fuel involved in not only transport sector but also in agricultural sector and also fast depletion of fossil fuels, the search for alternate fuels has become pertinent apart from effective fuel utilization which has been the concern of the engine manufacturers, users and researchers involved in combustion & alternate fuel research.

Vegetable oils and alcohols are promising substitutes for diesel fuel as they are renewable in nature. Out of many techniques available, blending is simple technique, to induct alcohol into diesel engine [Wang *et al*, 2008; Lalit Kumar *et al*, 2012; Satish Kumar *et al*, 2013]. Alcohols have low cetane number and hence engine modification is necessary for use as fuel in diesel engine [Murali Krishna *et al*, 2014; Murali Krishna *et al*, 2015]. On the other hand, vegetable oils have comparable properties in comparison with diesel fuel. The idea of using vegetable oil as fuel has been around from the birth of diesel engine. Rudolph diesel, the inventor of the engine that bears his name, experimented with fuels ranging from powdered coal to peanut oil. [Cummins, 1993]. Several researchers experimented the use of vegetable oils as fuel on

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Research Article

Experimental Investigations on Performance Parameters with Low Heat Rejection Diesel Engine with Varied Air Gap Thickness

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Abstract

Conservation of fossil fuels is gaining momentum along with adapting alternative fuel technology methods for the researchers and manufacturers involved in combustion research. The concept of low heat rejection (LHR) engine is to minimize heat flow to the coolant by providing thermal resistance in the path of heat flow to the coolant and thus increase thermal efficiency. It has significant characteristics of higher operating temperature, maximum heat release, and ability to handle low calorific value fuel. Investigations were carried out to evaluate the performance of diesel engine with air gap insulated low heat rejection (LHR–3) engine consisting of air gap insulated piston with superni crown , air gap insulated liner with superni insert and ceramic coated cylinder head with neat diesel with varied air gap thickness and injection timing. Performance parameters of brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, coolant load and volumetric efficiency were determined at various values of brake power. The optimum air gap thickness was found to be 2.8 mm with LHR–3engine with diesel operation. LHR engine with neat diesel operation showed deteriorated performance at manufacturer's recommended injection timing of 27^o bTDC (before top dead center) and the performance improved marginally with advanced injection timing of 28.5^o bTDC in comparison with conventional engine (CE) at 27^{o}bTDC.

Keywords: *Conservation of diesel, conventional engine, LHR engine, Performance.*

1. Introduction

In the scenario of i) increase of vehicle population at an alarming rate due to advancement of civilization, ii) use of diesel fuel in not only transport sector but also in agriculture sector leading to fast depletion of diesel fuels and iii) increase of fuel prices in International market leading to burden on economic sector of Govt. of India, the conservation of diesel fuel has become pertinent for the engine manufacturers, users and researchers involved in the combustion research. [Matthias Lamping et al, 2008].

The nation should pay gratitude towards Dr. Diesel for his remarkable invention of diesel engine. Compression ignition (CI) engines, due to their excellent fuel efficiency and durability, have become popular power plants for automotive applications. This is globally the most accepted type of internal combustion engine used for powering agricultural implements, industrial applications, and construction equipment along with marine propulsion. [Cummins *et al,* 1993; Avinash Kumar Agarwal *et al,* 2013].

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The concept of LHR combustion chamber is to reduce coolant losses by providing thermal resistance in the path of heat flow to the coolant, there by gaining thermal efficiency. Several methods adopted for achieving LHR to the coolant are ceramic coated engines and air gap insulated engines with creating air gap in the piston and other components with low-thermal conductivity materials like superni (an alloy of nickel), cast iron and mild steel etc.

LHR combustion chambers were classified as ceramic coated (LHR–1), air gap insulated (LHR–2) and combination of ceramic coated and air gap insulated engines(LHR–3) combustion chambers depending on degree of insulations. Experiments were conducted with neat diesel operation with ceramic coated diesel engine [Paralak *et a*l, 2005; Ekrem *et al,* 2006; Ciniviz *et al,* 2008; Janardhan et al, 2014; Janardhan et al, 2015]. They reported that brake specific fuel consumption decreased by 3-4% with ceramic coated diesel engine in comparison with conventional engine. Creating an air gap in the piston involved the complications of joining two different metals. Investigations were carried out on air gap insulated piston with neat diesel operation [Parker et al, 1987].

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Research Article

Experimental Investigations on Exhaust Emissions with Low Heat Rejection Diesel Engine with Crude Vegetable Oil with Magnetic Induction

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Abstract

In the scenario of fast depletion of fossil fuels and increase of pollution levels the search for alternative fuels has become pertinent. Particulate emissions and oxides of nitrogen are exhaust emissions from diesel engine cause health hazards once they are inhaled in. They also cause environmental impact. Hence control of these pollutants is an immediate task and urgent. Crude vegetable oils are important substitutes for diesel fuel, as they are renewable, and have comparable properties with diesel fuel. However, drawbacks associated with crude vegetable oil of high viscosity and low volatility which cause combustion problems, call for low heat rejection (LHR) engine with its significant characteristics of maximum heat release and ability to handle the low calorific value fuel. LHR engine consisted of ceramic coated cylinder head. A hydrocarbon fuel was polarized by exposure to external force such as magnetism. Exhaust emissions of particulate emissions and oxides of nitrogen (NO_x) were determined at full load operation with conventional engine (CE) and LHR engine with and without magnetic induction with vegetable oil operation. LHR engine with crude vegetable oil operation with magnetic induction improved exhaust emissions when compared with CE with vegetable oil operation.

Keywords: *Alternative fuels, Vegetable oil, Low heat rejection, Exhaust emissions*

1. Introduction

Fossil fuels are limited resources; hence, search for renewable fuels is becoming more and more prominent for ensuring energy security and environmental protection. It has been found that the vegetable oils are promising substitute for diesel fuel, because of their properties are comparable to those of diesel fuel. They are renewable and can be easily produced. When Rudolph Diesel, first invented the diesel engine, about a century ago, he demonstrated the principle by employing peanut oil. He hinted that vegetable oil would be the future fuel in diesel engine [Acharya, 2009]. Several researchers experimented the use of vegetable oils as fuel on conventional engines (CE) and reported that the performance was poor, citing the problems of high viscosity, low volatility and their polyunsaturated character. It caused the problems of piston ring sticking, injector and combustion chamber deposits, fuel system deposits, reduced power, reduced fuel economy and increased exhaust emissions [Venkanna *et al*, 2009; Misra *et al*, 2010; No.Soo-Young, 2011; Avinash Kumar *et al*, 2013].

The drawbacks associated with biodiesel (high viscosity and low volatility) call for hot combustion chamber, provided by low heat rejection (LHR) combustion chamber. The concept of the LHR engine is reduce heat loss to the coolant with provision of thermal resistance in the path of heat flow to the coolant. Three approaches that are being pursued to decrease heat rejection are (1) Coating with low thermal conductivity materials on crown of the piston, inner portion of the liner and cylinder head (LHR–1 engine), (2) air gap insulation where air gap is provided in the piston and other components with low-thermal conductivity materials like superni (an alloy of nickel),cast iron and mild steel (LHR–2 engine) and (3).LHR –3 engine contains air gap insulation and ceramic coated components.

Experiments were conducted on LHR-1 engine with vegetable oil. [Murali Krishna *et al,* 2012; Ratna Reddy *et al,* 2012; Kesava Reddy *et al,* 2012;]. They reported from their investigations, that LHR-1 engine at an optimum injection timing of 31° bTDC with vegetable oil operation at full load operation–decreased particulate emissions by 25–30% and increased NO_x levels, by 30–35% when compared with neat diesel operation on CE at 27° bTDC.

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Full Length Article

Investigation on performance and emission characteristics of EGR coupled semi adiabatic diesel engine fuelled by DEE blended rubber seed biodiesel

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Start of injection timing
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ABSTRACT

The test case was semi adiabatic diesel engine (SADE) produced by thermal barrier 8 YSZ (Yttria Stabilized Zirconia) ceramic coated cylinder head and liner with bond coat NiCrAl as an intermediate layer and coupled with an EGR (exhaust gas recirculation) of 10% constant rate. The test fuels injected directly into the combustion chamber are diesel and blend A15B85 by vol. (Additive Diethyl Ether 15% + Rubber seed based Biodiesel 85%). Throughout the experimentation, a constant compression ratio 18:1, fuel injection pressure 190 bar and speed 1800 rpm. Load from 0% to 100% and start of injection (SOI) timing from 30^0 BTDC to 35^0 BTDC were varied to investigate performance, in-cylinder pressure and emission parameters of SADE and ordinary diesel engine (ODE) fuelled by test fuels. It was found that advancement of SOI timing improved all the investigated parameters except NOx emissions. Compared to ODE with diesel at any specific SOI timing, the test case with blend found to be favourable. The optimum results of SADE were 7% enhancement of BTE with the reduction in BSEC by 5.5%, particulates by 48.5%, NOx by 19.5% and exhaust gas temperature by 18.5% found with the blend at 33^0 BTDC with higher load compared to ODE with neat diesel at 30^0 BTDC. The optimum configuration of ODE found to be diesel fuel at 34^0 BTDC with higher load.

Introduction

The objective of the current study is to present a better viable solution to an ordinary diesel engine fuelled by fossil diesel. Even though many technological advancements to improve diesel engine efficiency and emissions were made, still much remains to investigate. The chief hurdles of the ordinary diesel engine at normal operating conditions are low efficiency (only about 29–30%) and higher exhaust emissions like particulate matter, CO, unburnt HC, CO2 etc. The various reports published in recent years on fossil fuels showed a rapid decline in its reserves and strongly suggests for alternatives. Hence, in the current study an attempt is made to address all the above problems through a slight modification (Thermal Barrier Coating) to core engine components along with 100% renewable fuel (blend of rubber seed based biodiesel and diethyl ether additive) operation. Also, an attempt is made to find out the optimum engine operating configuration for the blend A15B85.

The acute problems faced by the world regarding conventional/fossil-based energy were the rapid decline in proved reserves and the damage to the atmosphere by fossil pollutants emitted from internal combustion engines that currently reached a wholly insupportable conclusion and needs sustainable addressing through technological advancements besides adopting alternative energy strategy. Significant research progress [1] regarding biodiesel acknowledged it as environmentally friendly fuel and potential alternative and also found that the properties of biodiesel were directly related to the type of source feedstock. Review of different studies [2,3] regarding biodiesel as alternative fuel in compression ignition engine found that brake thermal efficiency (BTE), CO, HC and Smoke were reduced significantly whereas brake specific fuel consumption (BSFC) and NOx emissions increased. It was found [4] that CI engine fuelled by a blend of diesel and low percentage biodiesel showed improvement in BTE, ignition delay, smoke, CO and HC compared to diesel fuel. The presence of toxic compounds in the oil sources like Jatropha, Karanja and Rubber seed makes them unfit for human consumption (non-edible) and hence can be

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Analysis of EGR Coupled Less Heat Rejection Model of Diesel Engine with Blends of Jatropha Biodiesel, Diesel and Diethyl Ether: An Experimental Approach

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ABSTRACT

The experimental investigation on a less heat rejection model (LHRM) of the diesel engine was done with the objective to improve the performance and emission characteristics. The LHRM has a bond coat of NiCrAl interposed between the thermal barrier ceramic coated cylinder head and liner of the engine. The model is coupled with exhaust gas recirculation (EGR) system at a constant rate of 10 vol.%. The test fuels are neat diesel for the non-coated engine (NCE) and blends with different ratios of diesel-Jatropha biodiesel, keeping a constant ratio of additive diethyl ether (DEE) for the LHRM. The load was varied from 0 to 100 % and injection timing (IT) from 29° to 34° BTDC. The performance parameters of both engines improved significantly with the advancement of the injection timing. The NOx emissions reduced with no effect on BSEC, BTE and smoke levels with 10 % EGR rate. The optimum blend and IT for LHRM are D20JB60A20 by vol. (20 % of diesel + 60 % of Jatropha biodiesel + 20 % of additive DEE) and 32° BTDC as the maximum enhancement of about 6 to 7 % in peak BTE with a reduction in BSEC by 9.5 %, EGT by 18 %, VE by 2 to 3 %, smoke level by 44.5 % and NOx emissions by 14.2 % were found compared to NCE with diesel at normal operating conditions. At advanced injection timings with a higher load, in comparison to NCE, LHRM showed significant improvement in all of the investigated parameters.

Keywords: Less heat rejection model; yttria-stabilized zirconia; exhaust gas recirculation; injection timing; diethyl ether additive; Jatropha biodiesel.

NOMENCLATURE

LHRM	less heat rejection model
NCE	non-coated engine
JB	jatropha biodiesel
DEE	diethyl ether
YSZ	yttria stabilized zirconia
NiCrAl	nickel-chromium-aluminum
EGR	exhaust gas recirculation
BTDC	before top dead center
BTE	brake thermal efficiency
EGT	exhaust gas temperature
BSEC	brake specific energy consumption
VE	volumetric efficiency

Effect of Copper Coated Piston on Thermal and Structural Stability of Four Stroke SI Engine Combustion Chamber

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Abstract

The heat from combustion is not fully converter to work as heat leak from inlet and outlet valve seat. Thermal coat studies have been suggesting that heat loss can be reduced by metal coating on engine combustion chamber. The objective of this work is to study the effect of copper coating on performance of lubricating oil as it has evaporative temperature limit around 280^0Cand its effect on life of piston. Experimentally it is difficult to check the temperature flow between piston and liner wall where the lubricating oil presents, therefore a numerical method of finite element method is adopted. Modeling is created using solid works; boundary conditions are calculated analytically using empirical formulas. It is observed that copper coating enhances the heat transfer by pre flame propagation and piston experienced wear and cracks in long run.

Keywords: copper coat, piston, liner, SI engine, thermal analysis

1. Introduction

Higher efficiencies, lower specific fuel consumptions and reduce emissions in modern internal combustion (IC) engines has become the center of attention to engine researchers and manufacturers. The global concern over the depletion of fossil fuels and the more stringent emissions regulations has placed the obligation on the engine industry to produce practical, economical and environmentally conscious solutions to power our automobiles. Heat utilization is one of the primary loss mechanisms in an internal combustion engine and it plays a crucial role in all aspects of engine operation. As a result, the want to better understand the effects of heat transfer on engine dynamics has led to a great deal of work in the field.

Silvio Memme[1] investigated and compared a baseline copper coating and a metal TBC. It was found reducing surface roughness of both coatings increased in-cylinder temperature and pressure as a result of reduced heat transfer through the piston crown. These increases resulted in small improvements in both power and fuel consumption, while also having measurable effect on emissions. Engine modification with copper coating on piston crown and inner side of cylinder head improves engine performance as copper is better conductor of heat and good combustion is achieved with copper coating. [2-3]. Muralikrishna etal.[4-6] studies the performance of SI engine by changing fuel composition, change of combustion chamber design and with provision of catalytic converter. Methanol blended gasoline (gasoline blended with methanol, 20%, by vol) improved engine performance and decreased pollution levels when compared with pure gasoline on CE. Ravindra Gehlot et.al.[7] analyzed ceramic coated diesel engine piston and found a significant increase in the pistons top surface temperature occurs with coating having holes. Although, the substrate temperature is decreasing with increase the radius of the holes. S.Srikanth Reddy et.al.[8] performed thermal analysis using ANSYS and optimized the piston using finite element analysis. The influence of ceramic coating thickness on temperature variations are studied by finite element method using ANSYS. S. Krishnamani et.al.[9], The temperature distribution analyses were conducted for the ceramic coating thickness of 0.3 mm over the piston crown surface. The results of the piston coated with two different coatings were analyzed. Dr.K.Kishor determined the temperature distribution across

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2nd International Conference on Materials Manufacturing and Design Engineering

Non-Destructive Analysis of FSW Process and Comparison With Simulation and Microstructural Analysis

T.Pavan kumar[1*], P.Prabhakar Reddy[2]

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Abstract

Friction Stir Welding is an evolving metal joining technique and is mostly used in joining materials which cannot be easily joined by other available welding techniques. It is a technique which can be used for welding dissimilar materials also. The strength of the weld joint is determined by the way in which these material are mixing with each other, since we are not using any filler material for the welding process the intermixing has a significant importance. The complication with the friction stir welding process is that there are many process parameters which effect this intermixing process such as tool geometry, rotating speed of the tool, transverse speed etc.,In this study an attempt is made to compare the material flow and weld quality of various weldments by changing the parameters. Thermographic analysis is used to characterize the microstructure of the elements. Thermography is a non destructive, accurate and fast way of measurement of temperature of the welding process which influences the formation of microstructure and also material flow and strength of the formed weldment.. In this study the relationship between microstructures and temperatures are evaluated. Simulation studies are also conducted and compared with experimental studies . the study resulted in good correlation between the experimental and simulation studies.the study involved use of different tool profiles and a comparative study is done with resulted mechanical and microstructural properties.

Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.

Keywords: *Friction Stir Welding, non-Destructive Testing, mechanical properties, simulation*

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Non Destructive Analysis of Fsw Welds using Ultrasonic Signal Analysis

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Abstract. Friction Stir Welding is an evolving metal joining technique and is mostly used in joining materials which cannot be easily joined by other available welding techniques. It is a technique which can be used for welding dissimilar materials also. The strength of the weld joint is determined by the way in which these material are mixing with each other, since we are not using any filler material for the welding process the intermixing has a significant importance. The complication with the friction stir welding process is that there are many process parameters which effect this intermixing process such as tool geometry, rotating speed of the tool, transverse speed etc.,

In this study an attempt is made to compare the material flow and weld quality of various weldments by changing the parameters. Ultrasonic signal Analysis is used to characterize the microstructure of the weldments. use of ultrasonic waves is a non destructive, accurate and fast way of characterization of microstructure. In this method the relationship between the ultrasonic measured parameters and microstructures are evaluated using background echo and backscattered signal process techniques. The ultrasonic velocity and attenuation measurements are dependent on the elastic modulus and any change in the microstructure is reflected in the ultrasonic velocity.

An insight into material flow is essential to determine the quality of the weld. Hence an attempt is made in this study to know the relationship between tool geometry and the pattern of material flow and resulting weld quality the experiments are conducted to weld dissimilar aluminum alloys and the weldments are characterized using and ultra Sonic signal processing. Characterization is also done using Scanning Electron Microscopy. It is observed that there is a good correlation between the ultrasonic signal processing results and Scanning Electron Microscopy on the observed precipitates. Tensile tests and hardness tests are conducted on the weldments and compared for determining the weld quality.

1. Introduction

Friction Stir welding process is a significant metal joining process since its invention by The Welding Institute(TWI) in 1991[1].Friction Stir welding process is a joining process which employs a tool which rotates and travels along the joining surfaces which are clamped together. The tool is non-consumable and many types of tool profiles are employed for the welding purpose. Tool geometry is defined by the shoulder diameter, pin diameter, profile of pin and the pin length. The pin length is usually shorter than then the thickness of the plates. The pin is penetrated into the work pieces and the tool rotates and transverses along the centreline. The interaction that takes place between the tool & work piece gives rise to friction generating heat which in turn creates plastic deformation and the flow

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Parametric Simulation and Optimization of FSW Process

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Abstract

This thesis research implemented an existing thermo mechanical model of friction stir welding process, and studied the surrogate model-based optimization approach to obtain optimal process parameters for the modelled friction stir welding process. As an initial step, the thermo mechanical model developed by Zhu and Chao for friction stir welding of 304L stainless steel was replicated using ANSYS. The developed model was then used to conduct parametric studies to understand the effect of various input parameters like total rate of heat input, welding speed and clamping location on temperature distribution and residual stress in the work piece. With the data from the simulated model, linear and nonlinear surrogate models were constructed using regression analysis to relate the selected input process parameters with response variables. Constrained optimization models were formulated using surrogate models and optimization of process parameters for minimizing cost and maximizing throughput was carried out using improved harmony search algorithm. To handle the constraints, Deb's parameter-less penalty method was used and implemented in the algorithm. It is learned from this research that: (1) heat input is mainly constrained by the lower bound of the temperature for making good welds; (2) the optimal welding speed must balance the loss of heat input and the gain in productivity; (3) clamping closer to the weld is better than away from the weld in terms of lowering the peak residual stresses. Moreover, the nonlinear surrogate models resulted in a slightly better optimal solution than the linear models when wide temperature range was used. However, for tight temperature constraints, optimization on

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ICAAMM-2016

Vibration Isolation of the Wind Tunnel Drive System

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Abstract

The paper deals with the analysis of the wind tunnel drive to isolate the vibrations generated during testing. A wind tunnel is a tool used in aerodynamic research to study the effects of air moving past solid objects. Wind tunnels involve intricate study of various parameters by the addition of various accessories to the model. At the test section, the lift forces are predominant due to the vibrations. The aerofoil structure which is placed in the test section for study gets disturbed by the vibrations which effect the coefficient of lift parameter. Keeping in view all these effects, the study of vibrations is essential to minimize vibrational effects over mechanical components.

The torsional natural frequency of the wind tunnel system is found out by both Analytical method and Finite Element (or) Eigen value methods. The mode shapes are drawn. Mathematical modelling of the physical system is done. Critical speeds are calculated. The amplitudes of vibration prior to the introduction of damping were measured. Suitable Dampers are selected and placed under the wind tunnel system for vibration isolation. Damping pads are selected as they are a perfect match for this wind tunnel. Isolation of the vibrations are confirmed by both analytical calculations and practical values measured by the vibration analyzers.

Selection and Peer-review under responsibility ofthe Committee Members of International Conference on Advancements in Aeromechanical Materials for Manufacturing (ICAAMM-2016).

*Keywords:*Wind tunnel; Torsional vibrations; Critical speeds; Transmissibility; Damping; Isolators;

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ICMPC 2017

Influence of LASER CMM Process Parameters on Dimensional Inspection of Standard Spheres

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Abstract

LASER based inspection systems are widely used in precision manufacturing system in the recent years. LASER CMM in which a LASER probe attached to Co-ordinate measuring machine is capable rapid measurement of complex 3D sculptured geometry. These machines are capable of capturing large number of data points in the order of thousand of points per second with good accuracy. This inspection is non contact, suitable for fragile and soft components and it is faster and complete surface profile data available in least time. This paper describe various applications of LASER inspection for precision component like turbine blade wax pattern and ceramic core and also describes the development of land based power generation turbine blade through reverse engineering methodology.

Selection and/or Peer-review under responsibility of 7th International Conference of Materials Processing and Characterization.

Keywords: LASER CMM, Inspection, Ceramic cores, Wax patterns, Reverse Engineering

1. Introduction

LASER coordinate measuring machines (CMM) are widely used in non-contact dimensional inspection and reverse engineering applications. Reverse engineering is defined as the process of obtaining a geometric CAD model from 3D points acquired by scanning/ digitizing the existing products. LASER CMM consists of a LASER based probe head, in which LASER light falls on the surface to be measured and CCD camera mounted on head will detect the reflection. Based on triangulation principle, 3D coordinates of the surface are recorded. LASER CMMs are effectively used in Non Contact Inspection and Reverse Engineering applications. The exceptional accuracy and speed of the LASER CMM systems make them ideal for rapid inspection and verification applications. They excel at measuring gaps, sectional profiles, and feature heights, locations and overall surface comparison. The advantages of these machines includes large amount of data

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Investigation on the Performance of Photovoltaic Panel with Various Filters

(At rural areas of bale robe region in Africa continent)

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Abstract:**The world looking towards the alternative energy sources because the utilization of conventional fuel is more and its impact on the environment is also more.The solar power is clean, cheap and availability is plenty. The sun intensity is various from place to place and available at remote areas. Even though we are having plenty amount of solar energy availability but we are unable to utilize solar energy effectively due to wave length variation and intensity variation. Our endeavor is effective utilization of solar energy at robe region where there is no electricity. In robe region, the availability of sun light is 13 hours per day that is morning 6 am to evening 7 pm. This experiment conducts with different filters and without filter on photovoltaic panel to find the effective utilization and for best efficiency level. Around 90 days we conducted this experiment. Every day we taken reading from morning 8 am to evening 5 pm. The best power generation values considered from each filter.**

Keywords: Efficiency, Electricity, Energy, Filter, solar, Utilization.

1.INTRODUCTION

A photo voltaic cell [1] is device which converts heat energy into electrical energy. A typical solar module has an efficiency in the range of 33%.the left over energy is transformed into heat and this heat [2] emitted in the form radiation into atmosphere. The output efficiency drop owed to augment in temperature of the panel and not incident enough sun intensity on the panel due to atmosphere conditions. Many experiments conducted on solar panel to enhance the efficiency and output of the panel. The wave [3] length of sun light has a substantial impact on the competence of PV panels. The present existing PV panels retort well up to certain levels but not all wave lengths. Various PV modules designed to work effectively at various wave length liable on the ingredients use to produce them. The noticeable light spectrum [4] runs from approximate $460X10^{12}$ Hz 9red color to 760 X 10^{12} (Blue color). The following table.1 shows the various wavelengths of light spectrum.

TABLE:1. DIFFERENT WAVELENGTHS OF SPECTRUMS OF WHITE LIGHT[1]

Light color	Approximate Wave lengths(nm)
Red	630-790
Yellow	580-610
Green	490-580
Blue	460-490
White	380-790

2.EXPERIMENTAL

SETUP The system consisting of
1.Solar panels 100W (5 pieces) 2.Multi meters
3.connecting cables
4. Filter papers (4 types)
The PV module specifications shown in the Table.2.

TABLE:2. SPECIFICATIONS OF THE POLY CRYSTALLINE MODULE

Poly crystalline Blue cells	100 W
No of cells	72
Minimum power output	89 %
Maximum power	90 W
Voltage pmax	24 V
Current at Pmax	5.0 A
Short circuit current	5.7 A
Open circuit voltage	27.4 V
Cell operating temperature	-45^0 C to 85^0 C
Weight	9.3 Kg
Dimensions	Dimensions 1090 L X 665 W X 35 mm
Power tolerance	+ / - 5%

The total experiment arranged as following shown in Figure:1.

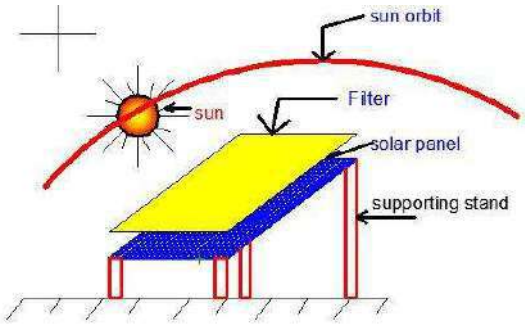

Figure:1. Experimental setup

The experiment conducted from March 1 2017 up to May 30 2017. The obtained readings shown in the following table.3. The voltage values and current values taken based on hour

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A hybrid PSO–BFO evolutionary algorithm for optimization of fused deposition modelling process parameters

Maraboina Raju[1] · Munish Kumar Gupta[2] · Neeraj Bhanot[3] · Vishal S. Sharma[1]

Received: 12 February 2018 / Accepted: 2 April 2018

Abstract
Fused deposition modeling (FDM), a well known 3D printing technology is widely used in various sorts of industrial applications because of its ability to manufacture complex objects in the stipulated time. However, the proper selection of input process parameters in FDM is a tedious task that directly affects the part performance. Here, in this work, the research efforts have been made to optimize the FDM process parameters in order to find out the best parameter setting as per the mechanical and surface quality perspectives by using hybrid particle swarm and bacterial foraging optimization (PSO–BFO) evolutionary algorithm. Taguchi L18 orthogonal array was used for the development of acro-nitrile butadiene styrene based 3D components by considering layer thickness, support material, model interior and orientation as a process parameters. Further, the relationships among selected FDM process parameters and output responses such as hardness, flexural modulus, tensile strength and surface roughness were established by using linear multiple regression. Then, the effects of individual process parameters on selected response parameters were examined by signal to noise ratio plots. Finally, a multi-objective optimization of process parameters has been performed with hybrid PSO–BFO, general PSO and BFO algorithm, respectively. The overall results reveal that the layer thickness of 0.007 mm, support material type sparse, part orientation of 60° and model interior of high density helps in achieving desired performance level.

Keywords Evolutionary algorithm · Mechanical properties · Optimization · Surface roughness · Rapid prototyping

Abbreviations

FDM	Fused deposition modeling
BFO	Bacterial foraging optimization
S/N	Signal to noise
FM	Flexural modulus
Ra	Surface roughness
MI	Model interior
SM	Support material
n	No. of bacteria in population
Nr	No. of reproduction steps
Ns	No. of swim
Pbest	Particle best position (PSO)
w_{max}	Maximum inertia weight (PSO)
$iter_{curr}$	Current iteration (PSO)
$c(I)$	Length of unit walk (BFO)
$Jcc\,(\theta, P\,(j,k,l))$	Cost function value (BFO)
PSO	Particle swarm optimization
ABS	Acro-nitrile butadiene styrene
H	Hardness
TS	Tensile strength
LT	Layer thickness
PO	Part orientation
AM	Additive manufacturing
Ned	No. of elimination–dispersion
Nc	No. of chemo-tactic steps
Pcd	Dispersion probability
Gbest	Global best position (PSO)
w_{min}	Minimum inertia weight (PSO)
$iter_{total}$	Total number of iteration (PSO)
$\phi\,(i)$	Direction angle of the jth step (BFO)

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Published online: 04 April 2018

CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY (A)
DEPARTMENT OF INFORMATION TECHNOLOGY

INTERNSHIPS 2017-18

Date: 22-09-2018

S.No.	Roll No.	STUDENT NAME	Organization Name	Duration
1.	160115737050	Jagannath Saragadam	Skylark Drones	14-05-2018 to 23-06-2018
2.	160116737010	Khushbu Jindal	Tech Mahindra	20-06-2018 to 17-08-2018
3.	160116737020	Pranavi Mankala	Srini Infotech	01-05-2018 to 01-06-2018
4.	160116737023	Gudur Sona	ECIT	28-05-2018 to 27-06-2018
5.	160116737002	V. Gouthami	Verzeo Edutech pvt Ltd.	01-05-2018 to 15-06-2018
6.	160116737013	Lakshmi Harika	Verzeo Edutech pvt Ltd.	01-05-2018 to 01-06-2018
7.	160117737011	Neha Dinesh Prabhu	Path Creators Company	04-11-2017 to 04-12-2017
8.	160116737026	C. Spandana	Inside View Technologies India Pvt. Ltd.	01-06-2018 to 29-06-2018
9.	160116737089	P.Durga Prasad	Ordanance Factory	04-06-2018 to 19-06-2018
10.	160116737029	N. Srinikitha	Inside View	01-06-2018 to 19-06-2018

1601-15-737-050

SKYLARK DRONES

28/03/2018

LETTER OF OFFER

Name: Jagannath Saragadam
Mob: +91 8985746575

Hello Jagannath Saragadam,

With reference to your application for **Internship** and subsequent discussion you had with us, we are pleased to make you an offer for the position of **Software Development Intern** with Skylark Drones Private Limited. Your assignment would be based in Bangalore.

Your Internship Terms will be as follows:

1) Your Internship Joining date is **14th MAY 2018.**

2) You will be paid a stipend of Rs. **15000**/-per month **(Rupees: Fifteen Thousand Only)** for the duration of the Internship. Your Internship would be the period of **6 (Six) Weeks**.

3) All cost of outstation travel with respect to the Project, if required by Skylark Drones, shall be paid by Skylark Drones.

4) You would not be entitled to any other benefit (s) during the period of your Internship with Skylark Drones.

5) Skylark Drones also reserves the right to withdraw the internship offer made to you even after the acceptance of such offer by you, if Skylark Drones becomes aware of any material information that may have been concealed or misrepresented by you at the time the offer was made by Skylark Drones.

Any change in your personal information stated by you verbally or in writing, shall be informed in writing to the **HR** Department within 3 working days.

Please note that your compensation structure and specific details are confidential. You are requested not to share your compensation details with others inside or outside of Skylark Drones.

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U72200MH2015PLC269129

Ref: HR/CERT/ C76685
Date:03-October-2018

Associate Name: **Khushbu Jindal**
GID : **C76685**
Address: S/O: Flat no 501, Badanika block, vbg garden,
Mehdipatnam,
Hyderabad 500008
Telangana

Subject: Internship Completion Certificate

This is to declare that **Ms. Khushbu Jindal** has successfully completed internship program with **Tech Mahindra** ltd from **20 June 2018** and has completed her internship titled **"UpX"** under the guidance of **Madhusudhan Madireddy** (Project Manager) on **17 August 2018**.

Best Wishes for your future endeavors.

Yours sincerely,
For Tech Mahindra Limited

SATPAL TALWAR
Group Manager - Human Resources.

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CIN:U72200TG2000PTC033229

Date: 02 July 2018

TO WHOM IT MAY CONCERN

This is to certify that **Pranavi Mankala** studying in CBIT has successfully completed internship for 2 months (May 2018 and June 2018) with us. She has designed and developed a **location tracking application** using Android, Java, Google Maps and SQLite. During the internship she was found to be dedicated and hardworking and her performance was satisfactory.

Srinivas Mankala

Director

SRINI INFOTECH PVT. LTD. CIN U72200TG2000PTC033229 HYDERABAD

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ECIT
ISO 9001:2008

PROJECT/INTERNSHIP COMPLETION CERTIFICATE

Date: 30/06/2018

This is to certify that **Ms. GUDUR SONI REDDY, Reg. No: 160116737024 & Ms. GUDUR SONA REDDY, Reg. No: 160116737023** are the students of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY, HYDERABAD** pursuing the Degree of **B.E.,** in **INFORMATION TECHNOLOGY** have undergone project work / internship titled **"AN APPLICATION FOR INVENTORY DATA MANAGEMENT"** in "ANDROID" under our guidance during the period from **28-05-2018** to **27-06-2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The students are punctual, hardworking and shown keen interest to produce the project output and results.

N.S. SEKHAR BABU
INCHARGE, CED

N.S. SEKHAR BABU
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HYDERABAD-500 062.

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TO WHOM IT MAY CONCERN

This is to certify that **Gouthami V** studying in

CBIT

has successfully completed an internship for 45 days (during the month of May-June 2018) with us working on

Introduction to Web Development.

During the internship, the student was found to be dedicated, hardworking and inquisitive.

Warm regards

V.V. Subrahmanyam

Director
Verzeo Edutech Pvt Ltd

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TO WHOM IT MAY CONCERN

This is to certify that **Lakshmi Harika G** studying in

CBIT (1601-16-737-013)

has successfully completed an internship for 45 days (during the month of May-June 2018) with us working on

Azure Cloud Computing.

During the internship, the student was found to be dedicated, hardworking and inquisitive.

Warm regards

V.V. Subrahmanyam

Director
Verzeo Edutech Pvt Ltd

PATH CREATORS

Sri Vaikunta Technologies Pvt Ltd

Date:

CERTIFICATE

This is to certify that Neha Dinesh Prabhu bearing Roll no. 177122, a student of Chaitanya Bharati Institute of Technology(Autonomous), Hyderabad, Telangana and Approved by AICTE, New Delhi successfully completed one month Internship Program on Robotics from 04-11-2017 to 04-12-2017 in Path Creators Company. During the period of her internship programme with us she was found punctual, hardworking and inquisitive.

We wish her every success in life.

PATH CREATORS HYDERABAD

Roma

Hr-Manager

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InsideView®

29th June, 2018

Internship Certificate

(1601-16-737-026)

This is to certify that Ms. Spandana C has joined us as a vacation Intern in Professional Services - India team from 1st Jun, 2018 to 29th June 2018.

During the above period, she has carried out her work satisfactorily & diligently under the supervision of manager.

We wish her the very best in your future endeavors.

Yours Sincerely,

InsideView Technologies (India) Pvt. Ltd.,

InsideView Technologies (India) Private Limited Hyderabad

Sesha Rao D
MD, India Operations

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16401/OFMK/HRD/IN-PLANT/18-19 Date: 19-06-2018

INTERNSHIP CERTIFICATE

This is to certify that the following individual has undergone In-plant training at this organization. Details are as follows:

1. Name of the Candidate	:	P.DURGA PRASAD
2. Father's Name	:	P.RAM REDDY
3. Branch/Year of Student	:	B.E (IT) II YEAR
4. Candidate Roll No.	:	160116737089
5. Name of the Institute	:	CBIT
6. Training Period	:	04-06-2018 TO 19-06-2018
7. No.Of Days Present	:	15

During the training period her/his conduct was **GOOD**.

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This is to certify that **Ms. Srinikitha Noothi** has joined us as a vacation **Intern** in **Professional Services - India** team from **1st Jun, 2018** to **29th June 2018.**

During the above period, she has carried out her work satisfactorily & diligently under the supervision of manager.

We wish her the very best in your future endeavors.

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REPORT

ON

SEPARATION OF ETHANOL AND WATER BY PROGRESSIVE FREEZE CONCENTRATION

At

Process Engineering & Technology Transfer Department

CSIR-Indian Institute of Chemical Technology,

Hyderabad

(23rd May 2018 to 1st July 2018)

Guide:
Dr. B. Satyavathi
Principal Scientist
CSIR-IICT
Hyderabad

Submitted by
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TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Ms.M Srilekha**, student of Chaitanya Bharathi Institute of Tech, CBIT Campus, Gandipet,, Kokapet, RR District, Hyd - 500 075 has undergone training in our organization from **11.06.2018** to **29.06.2018**. She has completed her project work on **Condenser Designing** with the **MSAT (Process Engineering) department**, **CTO Unit II** at Dr. Reddy's Laboratories Limited.

Her conduct during the training period was satisfactory and we wish her all success in future endeavors.

With best regards,
For Dr.Reddy's Laboratories Ltd.,

29/06/18

Authorized Signatory

Government of India
Department of Atomic Energy
NUCLEAR FUEL COMPLEX

BONAFIDE CERTIFICATE

This is to certify that K.B.MAHALAKSHMI has done her Project Work under my guidance during the period from 11-06-2018 to 12-07-2018 on the topic entitled ZIRCONIUM OXIDE PRODUCTION AND EXPERIMENTAL STUDY ON FILTRATION AND EVAPORATION OF SODIUM NITRATE ALONG WITH EVAPORATOR DESIGN FOR THE PROCESS with reference to the Zirconium Oxide Plant of Nuclear Fuel Complex.

It is ensured that the report does not contain classified or Plant operational live data in any form.

Signature:

Name: ANAND

Desgn. Of Guide: SO/D

Plant: ZOP

Hyderabad

Date 13/7/2018

Approved by

जॉनसन डिसूज़ा/JOHNSON D'SOUZA
वरिष्ठ प्रबंधक, जेडओपी/Sr. Manager ZOP

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Research paper

Recovery of Copper by Using Flotation Techniques and Microbe- Mineral Surface Interaction

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Abstract

According to research paper, copper recovery from high grade copper was make an effort treating with a chemolithotrophic microorganism, and Acidithiobacillus ferrooxidans bacteria. The aim of the present study is to understand the changes in Copper ore beneficiation based on surface chemical properties of bacteria during adaptation to high grade copper minerals and the projected consequences in flotation and bio-flotation processes .The utility of bio processing in the beneficiation of Copper ore through bio-flotation is demonstrated in this work. An autotroph Thiobacillusferroxidansbacteria is adapted to high grade mixed copper ore sample, which was supplied from HCL Malanjkhand Copper Plant, Open cast mines. According to the procedure the collection and activation of the bacterial strains of Acidithiobacillus ferrooxidans.In 9K media Culture bacteria was developed, added sufficient amount of nutrients and agitated the culture to enhance the growth at room temperature. Copper sample was adapted by repeated subcultures of bacteria. The surface characteristics were studied Zeta Potential by analysis at different Ph values and different time intervals. After that the samples were analyzed by Chemical Analysis in the Laboratory for the percentage of the Copper recovered from each sample and also calculated rate constant (k) by using Flotation kinetics. From the studies it was observed that the mineral adapted cells became more hydrophobic as compared to un adapted cells during bio-flotation .It was also noticed that there was no significant changes in the surface charge of bacteria before and after adaption. If the adaption of bacteria is high then the recovery of Copper is more.

Keywords: *Recovery, Culture preparation, Bio processing, flotation, Bio-flotation, Zeta Potential studies.*

1. Introduction

Quick progress is being done in mineral processing based on biological principle. Microorganisms (Acidithiobacillus ferrooxidans) can be used beneficially in mineral processing, from mining to waste disposal and management. Low-Grade ore, small and complicated ore bodies, waste ores, tailings and ores that are uneconomical to be recovered by traditional methods can be economical recovered by bioleaching. Microbe process provides an economic substitute for the mineral industry, when high-grade mineral reserves are being decreased.

Rapid industrialization around the world has increased the demand for metals slowly but gradually, thus led to the depletion of high grade ore due to large-scale exploitation of the high-grade ores. Thus it has all come to processing of lean grade ores to meet the requirements of the industries. Bio processing techniques possess eye-catching characteristic for reacting with complex ores. Use of various microorganisms in beneficiation process like bio-leaching, bio-flotation and bio-flocculation has become a reality.

New resources for metals must be developed with aid of novel technologies. Improvement of already exist mining technologies can result in metal recovery from sources that have not been of economical interest until today. Metal-winning process based on activity of microorganisms offer a possibility to obtain metals from mineral resources not accessible by conventional methods. for example, its application could result in extraction of gold, copper, nickel and zinc from sulphide ore without emission of sulphide emission of sulfur dioxide as occurs with conventional smelting technologies. The mineral industry and the community will benefit enormously from a successful mineral biotechnology.

The main copper mineral in the copper ore is chalcopyrite. Researchers have been striving for decades to understand the reasons for slow dissolution of chalcopyrite in both chemical and biological leaching reactions. The main problem hindering commercial application of bio hydrometallurgy processing of chalcopyrite is the slow dissolution rate. The bioleaching rate of other copper sulphides such as covellite CuS and chalcocite Cu2S are relatively high in the presence of iron oxidizing bacteria, since the mineral react favourable with ferric ion, the principle oxidant. However the solubilisation rate of chalcopyrite in an oxidizing medium is characteristically slow. Application of chalcopyrite bioleaching in heap and dump processes can potential result in lower cost and reduced environment impact of copper production, as well as a substantial increase in known-extractable resources of copper bearing minerals.

2. Materials and Methods

2.1. Materials

The high grade copper ore sample supplied from Hindustan Copper Limited ,Malanjkhand About 25kg from supplied sample was taken for processing .The high grade copper ore is subjected

for size analysis ,the result are given in table. Further and the ore was subjected for grinding to produce 65%-75µm particle sizes. The chemical analysis of the sample indicated 1.7%Cu and 2.8% Fe in the ore samples. Mineral samples of -75µm fractions were also subjected to Zeta potential meter for its surface study.

2.2 Culture Preparation

Microbial culture was developed from the tailings of Hindustan Copper Limited and recultured.The growth was carried out in 250 ml conical flasks containing 90 ml of the 9-K Media with 10 ml of inoculums (old culture), i.e.10% V/V inoculums without ore. The flasks were incubated at room temperature on a rotary shaker at 120 rpm. After 10 days the culture was ready for bioleaching tests.

Fig.1: Full Growned culture

Chemical used	Amount Required
FeSO4.7H2O	44.2 gm
(NH4)2 S04	3 gm
10N H2SO4	1ml
MgSO4.7H2O	0.5 gm
KCl	0.1 gm
pH-2.9,Temperature30ºC	

2.3 Flotation

Flotation is a process of separation and concentration based on differences in the physicochemical properties of interfaces. Flotation can take place either at a liquid–gas, a liquid–liquid, a liquid–solid or a solid–gas interface. In froth flotation, the flotation takes place on a gas–liquid interface. Hydrophobic particles, which may be molecular, colloidal, or macro-particulate in size, are selectively adsorbed or attached to and remain on the surface of gas bubbles rising through suspension, and are thereby concentrated or separated from the suspension in the form of froth. This ability to modify the floatability of minerals has made possible many otherwise difficult separations that are now common practice in modern mills. Flotation is widely used to concentrate copper, lead, and zinc minerals, which commonly accompany one another in their ores. Many complex ore mixtures formerly of little value have become major sources of certain metals by means of the flotation process.

2.4 Bio-Flotation

The bio flotation process concern the mineral response to the bacterium presence, which is essentially considered as interplay between microorganism and physico-chemical separation process.

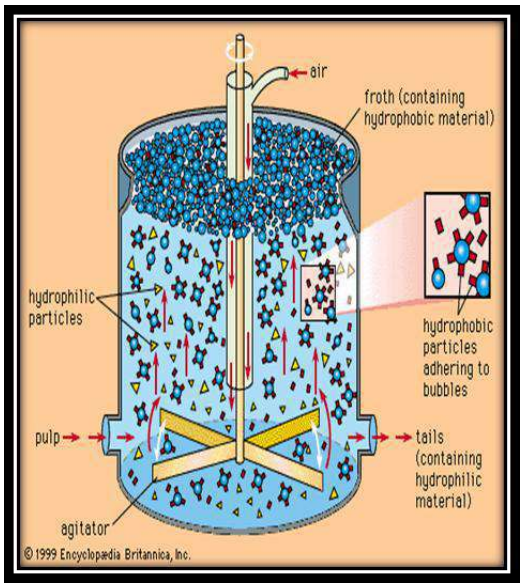


Fig.2: Flotation Mechanism

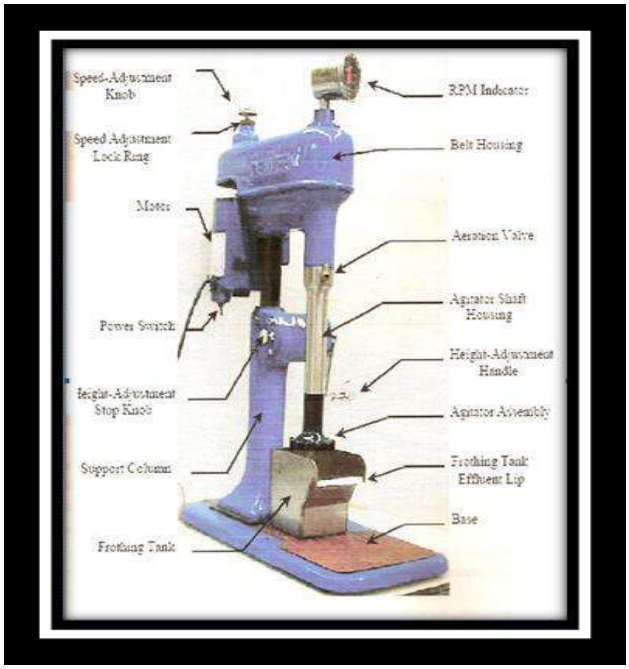


Fig.3: Denver Flotation Cell

The process of material being recovered by flotation from the pulp consists of three mechanisms:

- Selective attachment to air bubbles (or "true flotation").
- Entrainment in the water which passes through the froth.
- Physical entrapment between particles in the froth attached to air bubbles (often referred to as "aggregation").
- Minerals are classified into two types i.e. polar and non-polar. Polar minerals are those with strong covalent bond. These minerals react effectively with water and also having hydrophobicity in nature. Non-polar minerals characterized by weak molecular bond. These minerals are establishing the covalent bond together by Vander Waals forces. Non-polar surface not attached to the water molecules and then they are water repellent. Examples are graphite, sulphur; diamond and coal have natural floatability with a contact angle of 60 and 90 degree.

Formulation used for calculating recovery is:
Recovery = (Cc/Ff)*100
Where
C-Weight of final copper concentrate

c-% copper in concentrate
F-Weight of copper sample taken for flotation
f-% of copper in copper sample taken for flotation
2.5 Flotation reagents:
The mineral particles can only attach to the air bubbles if they are to some extent water-repellent, or hydrophobic. Having reached the surface, the air bubbles can only continue to support the mineral particles if they can form a stable froth, otherwise they will burst and drop the mineral particles. To achieve these conditions it is necessary to use the numerous chemical compounds known as flotation reagents. The classifications of different reagents are
Collectors :Minerals have to be hydrophobic so that they can float. To achieve this, collectors are added to the pulp and time is allowed for adsorption during agitation in what is known as conditioning period. Collectors are organic compound which make the minerals hydrophobic by making a layer on the surface, thus making the bubble to attach on the surface easily and thus float. Collectors are of two types non- ionizing and ionizing. Ionizing is of two types anionic and cationic. Cationic are water repellent. Anionic are divided into Oxyhydryl and Sulphydryl. Examples of oxyhydryl are carboxylic, sulphates and sulphonates. Sulphydryl consists of Xanthates and dithiophosphate. Apart from these bacterial proteins can also be used as collectors in flotation.

2.6 Frothers

They are added to stabilize the bubble formation in the pulp phase, to create a reasonable stable froth, to selectively drain the mineral and to increase the flotation kinetics. It should be able to act in water and air phase only. They should be able to create enough bubble strength. Widely used Frothers are crysylic acid, pine oil, Methyl iso butyl carbonyl (MIBC).

2.7 Regulators

This is used to reduce the action of collectors either by modifying the hydrophobocity on the surface of mineral. Thus then the reaction of the collectors most effective towards the minerals.
Types of regulators

- Activators
- Depressants
- pH regulators

Activators are reagents which enhance the chemical nature of the mineral surface thus changing to hydrophobic. E.g.: Copper Sulphate Depressants are reagents which render the mineral particle to hydrophilic by formation of hydrophilic coating at the surface. E.g.: Sodium Cyanide. pH regulators essentially regulate pH. They increase the selectivity by providing the stable condition for collectors. Xanthate is the most widely used collectors which has working range of 4-12.

2.8 Bacteria as Collector in Flotation

Same procedure is followed except that in the place of NaCN, a bacterium is used as Collector in flotation. The bacterium used is Thiobacillus Ferrooxidans which is given various interaction time of 20, 40 and 60 min with the ore before the experiment was started. The amount of bacteria (100,200,300 and 400ml) used for interaction with the ore was also changed. The Bacterium Thiobacillus Ferrooxidans was grown using 9K media for about 5 days at 350 C.
The result of the studies indicates an increase in the recovery in the percentage of Copper from 65% to 98.5%.

2.9 Zeta Potential Study

In this study the surface charge of the particles are measured by Zeta potential equipment the zeta potential is measured for the ore or Copper concentrate which is interacted with or without bacteria for different interval of time at different pH. The solution is poured into the cell. A charge of 200 volts is applied through the solution. The measured zeta potential is noted down for all the sample accordingly In order to study chemical changes, resulting from microbe mineral surface interaction, zeta potential measurements have been carried out by using full grown culture of Thiobacillus ferrooxidans. Initially, the studies were carried out on the Copper ore. For this purpose the ore was ground to -75 µm size fraction and subjected for zeta potential studies in the absence of Thiobacillus Ferrooxidans. From the figure we observe that the mineral possess negative zeta potential all over the pH range. We also observe increase in the potential of the particle as the pH decreases.
Analytical Method: Chemical Analysis:
After size analysis, quantitative analysis was carried out by volumetric analysis to analyze the percentage of Copper in the given sample.

3. Results & Discussion:

The results obtained from the experimental work are described and discussed below:

- ❖ Analyzing the variation of pH and Microscopic studies
- ❖ Flotation &Bio flotation studies
- ❖ Zeta Potential studies.
- ❖ Equilibrium and kinetic studies

3.1 Results of Flotation Studies

These results are drawn from the froth flotation:

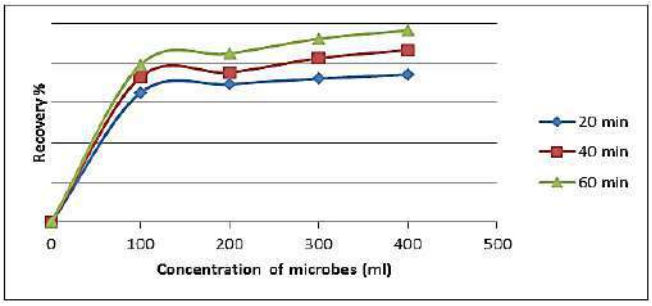
S.No.	Sample	Weight(gm)	Initial reading	Final reading	Difference	% of Copper	Recovery %
1	Froth	54.15	0ml	21.25ml	21.25ml	13.5	86
2	Tailing	445.84	21.25ml	22.75ml	1.5ml	0.95	49.7

3.2 Bacteria as Collector in Flotation

Same procedure is followed except that in the place of NaCN, a bacterium is used as collector in flotation. The bacterium used is Thiobacillus Ferrooxidans which is given various interaction time of 1hr, 4hr and 24hr with the ore before the experiment was started. The amount of bacteria (100,200,300 and 400ml) used for interaction with the ore was also changed. The Bacterium Thiobacillus Ferrooxidans was grown using 9K media for about 5 days at 350 C.

S.No.	Culture(ml)	Incubation Time(hr)	%Recovery
1.	100	24	82.82
2.	200	24	92
3.	300	24	98
4.	400	24	98.5

We can conclude from this comparison that the recovery of Copper has increased with the increase in the interaction time. The Copper recovery increased from 65 to 98.5 %. Thus we can conclude that interaction time of bacteria and
concentration of bacteria used are important factors in bio flotation. This is because these parameters changed the surface properties of the particle to hydrophobic.



Increase in Copper % in copper concentrate with increase in interaction time

3.3 Result of Zeta Potential Studies

In order to study chemical changes, resulting from microbe mineral surface interaction, zeta potential measurements have been carried out by using full grown culture of Thiobacillusferrooxidans. Initially, the studies were carried out on the ChalcoPyrite ore. For this purpose the ore was ground to -75 µm size fraction and subjected for zeta potential studies in the absence of ThiobacillusFerrooxidans. The results of the studies are given in figure. From the figure we observe that the mineral possess negative zeta potential all over the pH range. We also observe increase in the potential of the particle as the pH decreases.

Fig.4: Zeta Meter

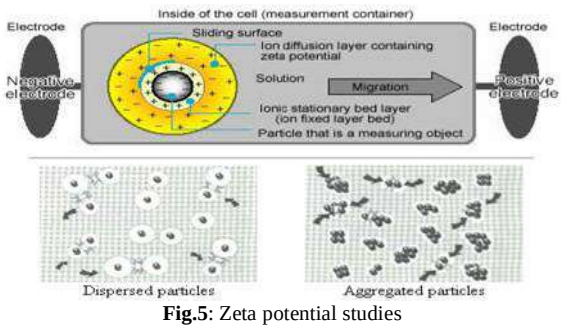
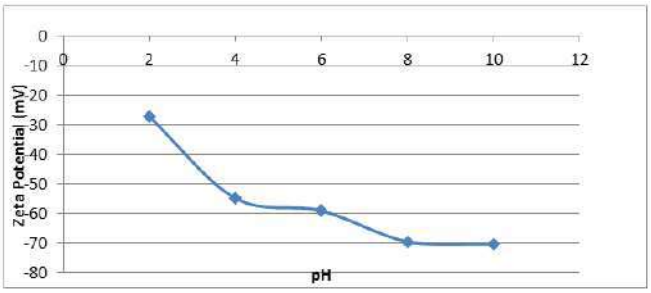


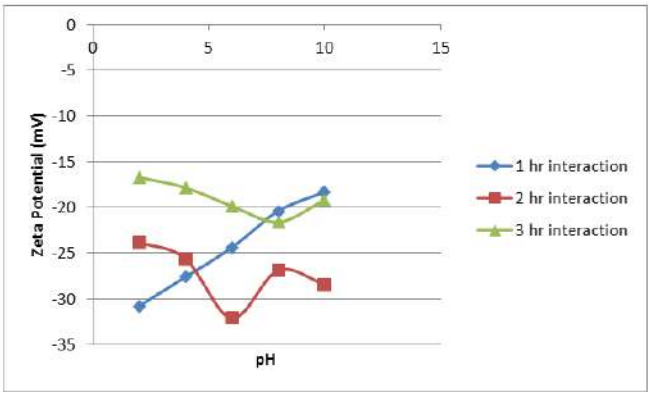
Fig.5: Zeta potential studies

Zeta potential of microbe mineral Interaction at pH 2

Conditioning time (min)	Zeta Potential (Ore)	Zeta Potential (with microbial interaction)
30	-36.7	-26.5
60	-37.2	-23.7
90	-34.5	-20.2
120	-35.6	-10.4



Potential of ore without bacterial interaction at different pH
Further, in order to study the microbe mineral interactions studies were carried out on the copper ore .



Potential of ore with bacterial interaction at different pH

The result indicates changes in zeta potential due to surface chemical changes. From the figure it may also be observed that concentrates of copper possess negative potential throughout the pH range. From the studies it is interesting to note that the variation in zeta potential was higher in zinc concentrate – microbe mineral interaction than that of lead concentrate microbe interaction. This variation may be due to the increased adsorption of microbes to galena than sphalerite. Hence, critical observation of the results indicate that variation in zeta potential may be exploited in selective flotation of lead zinc complex sulphide ores.

4. Conclusion

From the studies the following conclusion can be drawn:
1. The bacterium Thiobacillus ferrooxidans takes at least 4 to 5 days to grow into a fully grown culture.
2. Using bioflotation i.e. by using Thiobacillus ferrooxidans as collector, there is an increase in the recovery of Copper.
3. The maximum recovery was found to be 98.5% for copper. This recovery was achieved using 400 ml microbial culture at 24hr interaction time.
4. From the Zeta potential studies it was found that maximum interaction between the ore and the bacteria takes place between pH 2-2.5.
5. Bio flotation is environment friendly process, were the use of microbe can used both as collector and can also used in water

treatment plant. From the studies carried out it may be observed that the bacterial culture can be used in flotation of high grade copper ore as a substitute for xanthate with appreciable recovery and grade.

6. From the studies carried out it may be observed that the Thiobacillus ferrooxidanscan be effectively used in floatation for valuable metals from lean grade and high grade ores.

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Effects of operating Parameters on Recovery of non-floatable Coal by Column flotation

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Abstract

In this research paper, Investigation has done for comparison about mechanical flotation and Column flotation cell,, the similar properties were identified among mechanical flotation cell and column flotation cell for fine coal processing. Moreover the maximum values of operational variables are identified, those were essential to select in column flotation for desirable separation process. Therefore the frother height, Air flow rate, slurry flow rate, collector dosage, the wash water rate, the airflow rate and the pulp rate. The coal sample was collected from a classifying cyclone overflow stream consisting of nominally -500 μm material. The Proximate analyses of the coal sample were found to be 44.40%, 18.70%, 28.60% and 0.50%, respectively. Comparison of the column and mechanical flotation results indicated that column flotation was considerably more efficient than mechanical flotation for fine coal cleaning. High frother thickness and wash water addition during column flotation made it possible to obtain cleaner coals. The column flotation produced 15.60% product ash with 49.92% of clean coal and combustible recovery of 80.15%.

Keywords: Flotation cells, feed rate, Collector dosage, Airflow rate, slurry flow rate, pulp rate.

INTRODUCTION:

Flotation mechanism is one of the versatile processes to use and separate the fine coal cleanings extensively from 1918. Column flotation cell is a refined froth flotation method; it is elaborated as an alternative form of conventional flotation and mechanical flotation. The major role of the column flotation cell upon mechanical flotation contain outstanding separating capacity, a less capital and operating value, a low demand for plant area and flexibility to automatic control. The very essential parameter is differentiating between column flotation cell over mechanical flotation is the cell shape and the not in use of an impeller or a stator to get the air droplets. As per mechanical flotation air droplets were produced with the action of an impeller method although the air droplets are produced in column flotation with sprayer by the air compression process. Apart from this, clean coals are obtained in column flotation cell with addition of clean water with frother.

In flotation column, raw material was normally entered 3/4 height of the column by adding compression air through pervious material (sprayer) over the tailing output area of flotation column. Because of the coal particles travelling down combine along with the rise up bubbles of air in the collecting area. After, the attached lighter particles to the air bubbles go to cleaning section. The non floatable particles reaches to beneath of the flotation column, then carried out the segregation. The areas of the columns in the agitating section are most disadvantages, the major difficulties in the column height installations are at closed section of sparger. According to previous years, more number of design columns is incorporated to remove the difficulties to enhance recovery through producing micro bubbles. Few of the mare Leeds column, packed column, Flotaire column, Hydro chem. column, Jameson column, Microcel flotation column, Cyclone flotation column and Cyclonic column of micro bubble. In the previous works the column flotation cell performance indicated over and few parameters are identified that airflow rate, raw material feed rate, rate of wash water, thickness of the frother and collector dosage comparatively impact the performance of flotation.

As per research observations, increases the air flow rate, then increase the recovery it will gives high amount of yield and then it is going to be starts to decrease. Even though, many kinds of results come up from the studies done for the feed rate. Finch said that when the rate of raw material maximized, the holding period reduced and then the recovery enhanced. Even though, Goodland have confirmed that the reverse might be happen. As per research results conducted for cleaning water, it has confirmed that by the enhancing rate of washed water, grade is higher and lower recovery was obtained. As per more experimentation it was proved that instead of increase in the grade, and then the recovery do not reduced more. The parameters frother thickness and wash water rate are having same effect on flotation process.

Then the frother become hard, higher grade and lower recovery was obtained. The impact of collector dosage and frother concentration in flotation process is at most equal is recognized in mechanical flotation cell. According to different observations, at optimum value if collector dosage having an maximum level at that level recovery achieves the highest value in flotation.

In most of the research studies the cells were verified relatively, finally it has concluded that the column flotation cell produces a more recovery with less ash content, with the help of both the flotation cells attained washed coal, and having the ash percentages 11.50% and 12.30%, respective combustible recoveries are 80.10% and 76.50%, accordingly. Relatively, Harris, attained washed coals which are having the ash amount of 8.70% and 10.50% with grades of 35.30% and 30.10%, accordingly. Even though, Gu¨ney *et al*. (2002)has got that the

opposite is achievable and confirmed that column flotation cell is having less performance relatively compare to mechanical flotation cell. Turkey coal samples percentage of ash around 43.12% are separated with help of flotation column. Washed coals are attained the percentages of ash like 13.07%, 14.13% and 15.11% ,respective combustible recoveries are 19.10%,31.70% and 39.10%. Finally with the help of mechanical flotation cell , clean washed coals are attained by the ash percentages of 12.30%, 19.41% and 21.15% and the combustible recoveries of 34.10%, 63.80% and 72.10%, accordingly.

MATERIALS AND METHODS:

The diagrammatic performance of the small scale column flotation cell used for experimentation as per Fig. 1. The flotation column containing height of 140 cm circular column and 6cm of diameter, 14 L volume of Raw material collection tank arranged with a compressor to supply the air. There are two positive displacement pumps for feed entering and the tailing exit, measurement of flow device, above the 5cm top of the column a jet-type wash water system arranged.

Material Used

The raw material collected by the coal washeries from Baurine coal mine. The slurry from raw material obtained through classifying section of overflow of the cyclone containing normally – 500 μm sample. The chemical analysis of the sample results are shown in Table 1.

The coal sample characterization data are shown inTable2.It shows 70% of coal sample having -76 mm size of the particle, which is having ash content of 46.40% and also total sulfur of 0.55%. Therefore, the coal was investigated as proportionately more content of ash and less sulfur of coal.

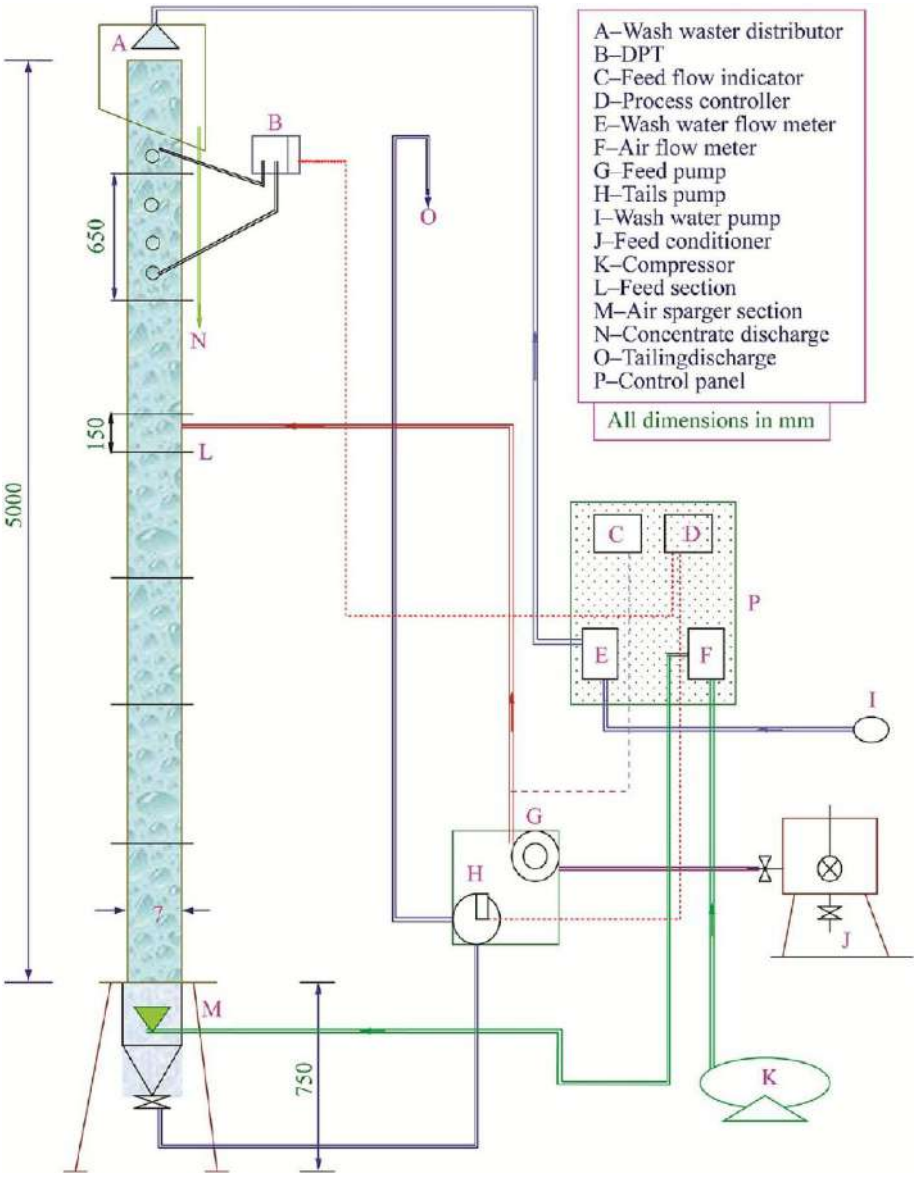

Figure 1. Column flotation cell Experimental set up

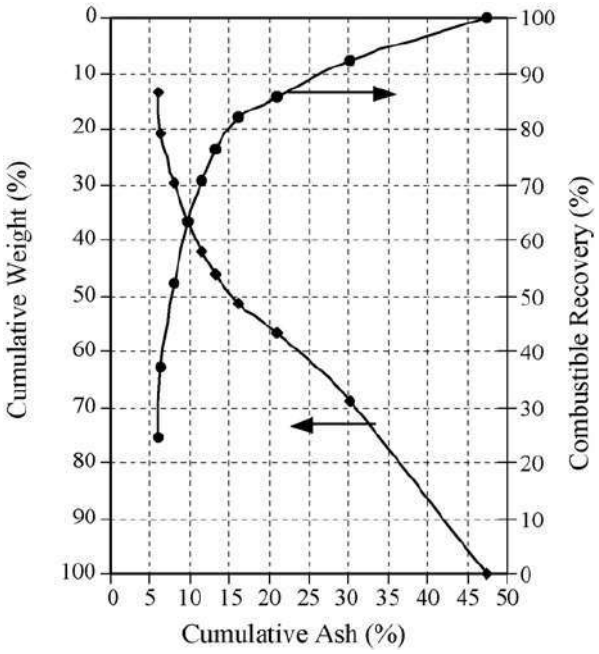

Figure 2. Cumulative weight in percentages and combustible recovery in percentages-vs.-cumulative ash percentages curves from tree (release) analysis experiment.

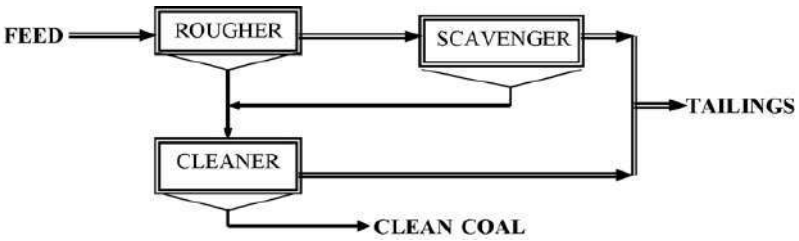

Figure 3. Rougher–scavenger–cleaner circuit diagram.

Table 1. Characterization of coal (air dry basis) (Proximate Analysis)

A_{ad} (%)	44.40
V_{ad} (%)	18.70
FC_{ad} (%)	28.60
Total sulfur (%)	0.55
Upper calorific value (kcal/kg)	4200

Table 2. For the various size fractions Distribution of weight, ash and combustible recoveries.

Size fraction (mm)	Weight retained (%)	A_{ad} (%)	Combustible Recovery (%)
+6	3.50	6.60	7.10
—6+2.8	3.77	4.45	7.41
—2.8+1.68	5.12	4.90	10.15
—1.68+0.85	6.04	19.45	10.42
—0.85+0.5	6.70	19.20	11.00
—0.5	59.27	59.14	47.95

By using release analysis calculated the affectivity of flotation which is given by Dell (1964) performed in (Fig.2).

Procedure:

One Kilo gram of coal sample was taken and added few amount of tap water was kept in conditioner tank by adding density of pulp is 10% (wt) and conditioning period is about 05 minutes. Therefore, the sample of coal was diluted uniformly with water. Then the kerosene is used as collector and MIBC as frother are added, stirred up agitating about 5 min up to required amount was obtained. Then the prepared pulp was kept into the column with speed of constant rate of feeding. The concentrate and tailing were attained in every stage of column flotation.

In column flotation experiment single step flotation was carried out to get maximum values of dosage collector, thickness of frother, rate of wash water, rate of airflow and density of the pulp. Another way, the system will produce the two products. Rougher clean coal and rougher tailing. Later on, it became clear that a single stage was not efficient enough for column flotation. Thus, rougher cleaner coal and rougher tailings were again sending to the column flotation cell then the cleaning process was carried out under the similar operating conditions. The circuit configuration of this process is shown in Fig.3

The combustible recovery attained from the flotation experiments was determined by the following equation:

$$Combustible\ Recovery\ (\%) = [Wc\text{X}\ (100\text{-}A_C) / W_f\ \text{X}\ (100A_f)]\ \text{X}\ 100$$

W_c is Clean coal by weight (%). W_f is feed by weight (%). A_c is clean coal ash content by weight (%).A_f is feed ash content by weight(%).

RESULTS AND DISCUSSION:

Impact of concentration of frother

The impact of concentration of frother on flotation column was determined there are MIBC was used as frother. It has selected like frother to give the much amount of froth at various concentrations like 20 mg/l, 25 mg/l, 30 mg/l and 35 mg/l. Table 3 indicates different MIBC concentrations results at end of the tests conducted.

Table 3. Impact of concentration of frother on the flotation column.

Frother (MIBC)	Collector (Kerosene)	Frother thickness	Rate of Wash water	Air flow rate	Feeding rate	Clean coal ash	Clean coal	Combustible recovery
(mg/lt)	(g/t)	(cm)	(cm/s)	(cm/s)	(cm/s)	(%)	yield (%)	(%)
20	1200	25	0.20	2.00	0.40	20.00	41.40	63.08
25	1200	25	0.20	2.00	0.40	20.45	44.04	66.73
30	1200	25	0.20	2.00	0.40	21.25	44.56	66.84
35	1200	25	0.20	2.00	0.40	23.40	45.02	65.68

Table 4. Impact of collector on flotation column.

Collector dosage (g/t)	Frother (MIBC)	Frother thickness	Rate of Washwater	Airflowrate	Feed rate	washed coal ash	Clean coal	Combustible recovery
(ppm)		(cm)	(cm/s)	(cm/s)	(cm/s)	(%)	yield (%)	(%)
500	25	25	0.20	2.00	0.40	18.15	41.32	63.00
1000	25	25	0.20	2.00	0.40	20.55	44.30	67.04
1500	25	25	0.20	2.00	0.40	21.10	44.87	67.43
2000	25	25	0.20	2.00	0.40	22.55	44.80	65.15

Then the concentration of frother was 20 mg/l, 25 mg/l and 30 mg/l, the combustible recoveries are 62.05%, 65.33% and 65.14%, accordingly. If frother concentration enhanced about 30 mg/l, then combustible recoveries were done. Then concentration of frother about 35 mg/l, combustible recovery reduced to 64.57%. According to frother concentration, ash content of washed coal achieved to maximum value (22.30%) by mineral entrainment. Finally maximum frother concentration determined by the test results was 25mg/l.

Impact of collector dosage

In this experiment selected collector was Kerosene. The experiment has performed at different dosages of kerosene like 500 g/t, 1000 g/t, 1500 g/t, 2000 g/t were shown Table 4. When dosage of collector increased 500 g/t to 2000 g/t it shown the content of ash percentage washed coal enhanced 18.15% to 22.55%, accordingly. On other hand, enhancing the dosage of the kerosene dose not given appropriate changes about combustible recovery. Then dosage collector is around 1000 g/t 20.55% and 67.04%, are ash content and combustible recovery

of clean coal respectively. Then the maximum amount of collector noted about 1200 g/t.

Impact of frother thickness

The test was performed at different frother thicknessesd like 15 cm, 20 cm, 25 cm, 30 cm were shown Table 5. if thickness of frother increased, and then ash content and combustible recoveries of coal were decreased. The very important consideration for this is by the result of frother thickness increased, the holding time of the particles in the frother section rise up and drop back potential of gangue minerals performed with rising of water because of reduces the froth with water. According to flotation experiments, maximum value of the frother thickness was calculated as 25cm.

Impact of the rate of wash water

According to the tests conducted by the different rates of wash water 0.10 cm/s, 0.20 cm/s, 0.30 cm/s, 0.40 cm/s were shown Table 6.Finally observed content of ash from clean coal attained more rate when wash water rate less. When rate of wash water 0.1 cm/s, then clean coal ash percentage 24.82%; if this is 0.40 cm/s, 17.45% reduced. Combustible recoveries at 0.1 cm/s and 0.40 cm/s are 70.36% and 51.66%, accordingly. As per flotation test it is check out thourouly the impact of the rate of wash water on flotation test, the maximum rate of wash water was determined about 0.2cm/s.

Impact of the airflow rate

As per Table 7 the experiment carried out based on different air flow rates like 1.50 cm/s, 2.00 cm/s, 2.50 cm/s and 3.00 cm/s. Apart from this, if rate of air flow is more, due to clean coal ash content. If air flow rates are 1.50 cm/s and 3.00 cm/s, then ash contents are 20.18% and 24.22%, accordingly. Because of ash content 2 cm/s the flow rate of air disorder in the flotation process. Stabilization of froth is also in disorder.

Table 5. Impact of thickness of frother on flotation column.

Frother thickness(cm)	Frother (MIBC) (ppm)	Reagent dosage (g/t)	Rate of Wash water (cm/s)	Airflow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
15	25	1200	0.20	2.00	0.40	22.10	45.90	68.10
20	25	1200	0.20	2.00	0.40	21.45	45.08	67.44
25	25	1200	0.20	2.00	0.40	20.95	44.48	66.97
30	25	1200	0.20	2.00	0.40	19.55	40.16	61.54

Table 6. Impact of rate of wash water on flotation column .

Wash water rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Air flow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.10	25	1200	25	2.00	0.40	25.82	50.51	71.36
0.20	25	1200	25	2.00	0.40	21.46	45.11	67.48
0.30	25	1200	25	2.00	0.40	19.06	41.46	63.92
0.40	25	1200	25	2.00	0.40	17.45	33.49	52.66

Table 7. Impact of air flow rate on flotation column.

Airflow rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
1.50	25	1200	25	0.20	0.40	20.28	41.28	62.68
2.00	25	1200	25	0.20	0.40	21.35	44.90	67.26
2.50	25	1200	25	0.20	0.40	22.95	45.80	67.17
3.00	25	1200	25	0.20	0.40	25.22	47.45	67.58

Table 8. Impact of feed rate on flotation column.

Feed rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.30	25	1200	25	0.20	2.00	21.55	46.25	68.11
0.40	25	1200	25	0.20	2.00	21.82	45.90	67.35
0.50	25	1200	25	0.20	2.00	21.60	45.50	66.94
0.60	25	1200	25	0.20	2.00	21.10	43.15	63.84

Impact of the pulp rate

The different experimental values of pulp densities were shown. For various pulp densities like 0.30 cm/s 0.40 cm/s, 0.50 cm/s and 0.60 cm/s, then content of clean coal ash almost equal. The combustible recoveries are 68.11%, 67.35%, 66.94% and 63.84% for similar feed rates, accordingly. When the feed rates are high then the combustible recoveries are less. If increase feed rate which reduced holding period of particles in flotation column and coal recovery less. Due to this maximum pulp density achieved 0.40 cm/s.

Differentiation of conventional flotation cell: According to conventional flotation cell results, 5 Lts of Denver flotation column used for laboratory scale. Optimal operating variables are estimated doing the series of experiments before studies. Therefore, the exact flotation test achieved with 10% pulp density (wt) also agitating speed was 900 rpm. The collector dosage (kerosene) was used around 1000 g/t and 20ppm concentration of frother.

Firstly, single-stage flotation experiment is carried out. After that attained rougher clean coal and rougher tailing are re-fed and floated again. The circuit configuration is relatively similar to flotation column.

As per single-stage column flotation cell clean coal was attained and ash percentage was 20.55% and combustible recovery was around 67.80%, similarly the mechanical flotation cell clean coal had an ash percentage of 22.15% and a combustible recovery was around 67.72%.

Table 9. Optimal operating variables of bituminous coal

Column diameter/height	Solids ratio (%)	Frother (MIBC) (ppm)	Reagent dosage (Kerosene) (g/t)	Frother thickness(cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Feed rate (cm/s)
7/150	10	25	1200	25	0.20	2.00	0.30

Table 10. Column flotation cell results under optimum conditions

Flotation stage	Product	Ash content (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	21.55	45.37	67.80
	Tailings	69.05	54.63	32.20
Rougher–scavenger–cleaner	Clean coal	15.60	50.92	81.85
	Tailings	80.59	49.08	18.15

Table 11. Mechanical flotation cell results under optimal conditions

Stages of flotation	Product	Content of ash (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	23.15	46.95	68.72
	Tailings	69.05	53.05	31.28
Rougher–scavenger–cleaner	Clean coal	19.52	53.70	82.32
	Tailings	79.95	46.30	17.68

Therefore, discarding of ash from both flotation system are found to be 53.63% and 50.26%, accordingly.

With help of rougher–scavenger–cleaner circuit system flotation column, clean coal was attained by higher combustible recovery 80.85% and lower ash percentage of 16.60%. Inspite

of that, mechanical flotation has given the clean coal which is having combustible recovery 81.32%. Even though, the ash percentage was obtained high amount of (19.52%). Therefore, discarding the ash from both flotation system found to be 67.15% and 58.90%, accordingly.

CONCLUSIONS

1. By increasing the collector dosage which increases the flotation yield. In spite of that, the above mentioned dosage, the flotation process opposite. By addition of much amount of MIBC and frother like Kerosene, then decreases the combustible recovery slowly. In other hand clean coal of ash amount was higher. The maximum reagent dosage and frother (MIBC) contents are determined 1000 g/t and 25 mg/l, accordingly.
2. If the frother thickness increases clean coal was attained. In addition to that, if the frother level increases, flotation yield decreases. The maximum frother thickness was obtained 30 cm.
3. By addining wash water gangue minerals performed with frother then it is re washed and removed them and passing through the washed coal,by increasing the rate of wah water, clean coals are attained. Even though, at higher wash water rates, constant frother not attained then slowly decreases the yield. The maximum rate of wash water calculated about 0.20cm/s.
4. As per lower airflow rate required frother thickness couldn't achieved, thus, the yield becomes less. At high air flow rates, the yield becomes more. Even though, above at particular rate, ash content of increases enormously. Then optimal air flow rate was calculated as 2cm/s.
5. By adding more feed rate, then the flotation yield was less. In addition to that ash content in clean coal do not vary at any point. The maximum feed rate obtained was 0.30cm/s.
6. If single stage flotation process carried out in both the flotation columns, do not extract much coal. The combustible recoveries of the tailings are determined 32.20% and 31.28%, accordingly, those are comparatively more values.
7. If the tailings from rougher and rougher clean coals are continuous floated separately for rougher–scavenger–cleaner circuit, more combustible recoveries (80.85–81.32%) are attained from both of the flotation cells .Moreover, by removal of ash, then it is identified column flotation cell was most efficient. Finally, by the column flotation cell the ash percentages of the bituminous coal was decreased from 46.50% to 17.60% and yield of combustible recovery was 80.85%. With help of mechanical flotation cell ash percentage of similar coal was decreased to 20.52% and 81.32%
8. The experimental values of the column flotation cell are very near to that of release analysis values. Apart from this, column flotation cell highly efficient than the mechanical flotation cell for fine coal separation.

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Effects of operating Parameters on Recovery of non-floatable Coal by Column flotation

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Abstract

In this research paper, Investigation has done for comparison about mechanical flotation and Column flotation cell,, the similar properties were identified among mechanical flotation cell and column flotation cell for fine coal processing. Moreover the maximum values of operational variables are identified, those were essential to select in column flotation for desirable separation process. Therefore the frother height, Air flow rate, slurry flow rate, collector dosage, the wash water rate, the airflow rate and the pulp rate. The coal sample was collected from a classifying cyclone overflow stream consisting of nominally -500 μm material. The Proximate analyses of the coal sample were found to be 44.40%, 18.70%, 28.60% and 0.50%, respectively. Comparison of the column and mechanical flotation results indicated that column flotation was considerably more efficient than mechanical flotation for fine coal cleaning. High frother thickness and wash water addition during column flotation made it possible to obtain cleaner coals. The column flotation produced 15.60% product ash with 49.92% of clean coal and combustible recovery of 80.15%.

Keywords: Flotation cells, feed rate, Collector dosage, Airflow rate, slurry flow rate, pulp rate.

INTRODUCTION:

Flotation mechanism is one of the versatile processes to use and separate the fine coal cleanings extensively from 1918. Column flotation cell is a refined froth flotation method; it is elaborated as an alternative form of conventional flotation and mechanical flotation. The major role of the column flotation cell upon mechanical flotation contain outstanding separating capacity, a less capital and operating value, a low demand for plant area and flexibility to automatic control. The very essential parameter is differentiating between column flotation cell over mechanical flotation is the cell shape and the not in use of an impeller or a stator to get the air droplets. As per mechanical flotation air droplets were produced with the action of an impeller method although the air droplets are produced in column flotation with sprayer by the air compression process. Apart from this, clean coals are obtained in column flotation cell with addition of clean water with frother.

In flotation column, raw material was normally entered 3/4 height of the column by adding compression air through pervious material (sprayer) over the tailing output area of flotation column. Because of the coal particles travelling down combine along with the rise up bubbles of air in the collecting area. After, the attached lighter particles to the air bubbles go to cleaning section. The non floatable particles reaches to beneath of the flotation column, then carried out the segregation. The areas of the columns in the agitating section are most disadvantages, the major difficulties in the column height installations are at closed section of sparger. According to previous years, more number of design columns is incorporated to remove the difficulties to enhance recovery through producing micro bubbles. Few of the mare Leeds column, packed column, Flotaire column, Hydro chem. column, Jameson column, Microcel flotation column, Cyclone flotation column and Cyclonic column of micro bubble. In the previous works the column flotation cell performance indicated over and few parameters are identified that airflow rate, raw material feed rate, rate of wash water, thickness of the frother and collector dosage comparatively impact the performance of flotation.

As per research observations, increases the air flow rate, then increase the recovery it will gives high amount of yield and then it is going to be starts to decrease. Even though, many kinds of results come up from the studies done for the feed rate. Finch said that when the rate of raw material maximized, the holding period reduced and then the recovery enhanced. Even though, Goodland have confirmed that the reverse might be happen. As per research results conducted for cleaning water, it has confirmed that by the enhancing rate of washed water, grade is higher and lower recovery was obtained. As per more experimentation it was proved that instead of increase in the grade, and then the recovery do not reduced more. The parameters frother thickness and wash water rate are having same effect on flotation process.

Then the frother become hard, higher grade and lower recovery was obtained. The impact of collector dosage and frother concentration in flotation process is at most equal is recognized in mechanical flotation cell. According to different observations, at optimum value if collector dosage having an maximum level at that level recovery achieves the highest value in flotation.

In most of the research studies the cells were verified relatively, finally it has concluded that the column flotation cell produces a more recovery with less ash content, with the help of both the flotation cells attained washed coal, and having the ash percentages 11.50% and 12.30%, respective combustible recoveries are 80.10% and 76.50%, accordingly. Relatively, Harris, attained washed coals which are having the ash amount of 8.70% and 10.50% with grades of 35.30% and 30.10%, accordingly. Even though, Gu¨ney *et al*. (2002)has got that the

opposite is achievable and confirmed that column flotation cell is having less performance relatively compare to mechanical flotation cell. Turkey coal samples percentage of ash around 43.12% are separated with help of flotation column. Washed coals are attained the percentages of ash like 13.07%, 14.13% and 15.11% ,respective combustible recoveries are 19.10%,31.70% and 39.10%. Finally with the help of mechanical flotation cell , clean washed coals are attained by the ash percentages of 12.30%, 19.41% and 21.15% and the combustible recoveries of 34.10%, 63.80% and 72.10%, accordingly.

MATERIALS AND METHODS:

The diagrammatic performance of the small scale column flotation cell used for experimentation as per Fig. 1. The flotation column containing height of 140 cm circular column and 6cm of diameter, 14 L volume of Raw material collection tank arranged with a compressor to supply the air. There are two positive displacement pumps for feed entering and the tailing exit, measurement of flow device, above the 5cm top of the column a jet-type wash water system arranged.

Material Used

The raw material collected by the coal washeries from Baurine coal mine. The slurry from raw material obtained through classifying section of overflow of the cyclone containing normally – 500 μm sample. The chemical analysis of the sample results are shown in Table 1.

The coal sample characterization data are shown inTable2.It shows 70% of coal sample having -76 mm size of the particle, which is having ash content of 46.40% and also total sulfur of 0.55%. Therefore, the coal was investigated as proportionately more content of ash and less sulfur of coal.

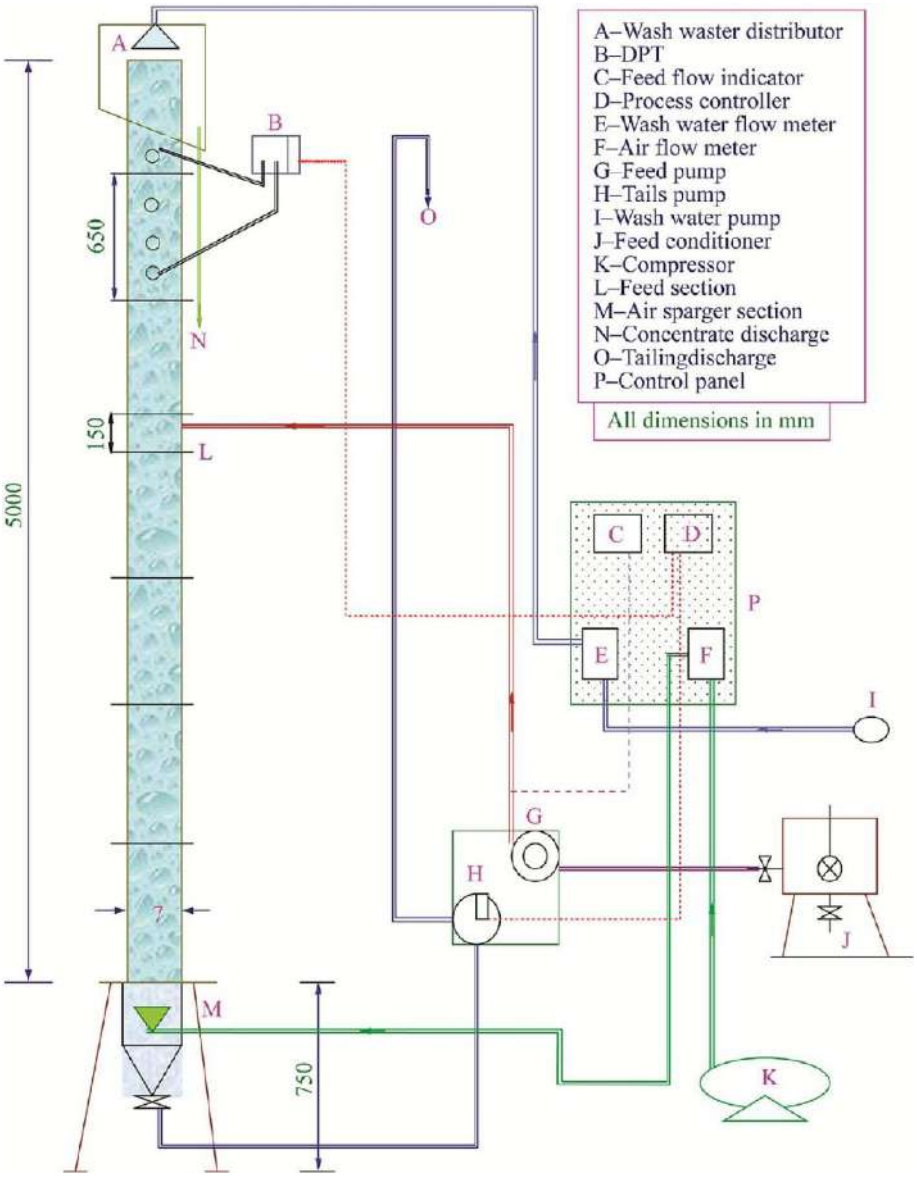
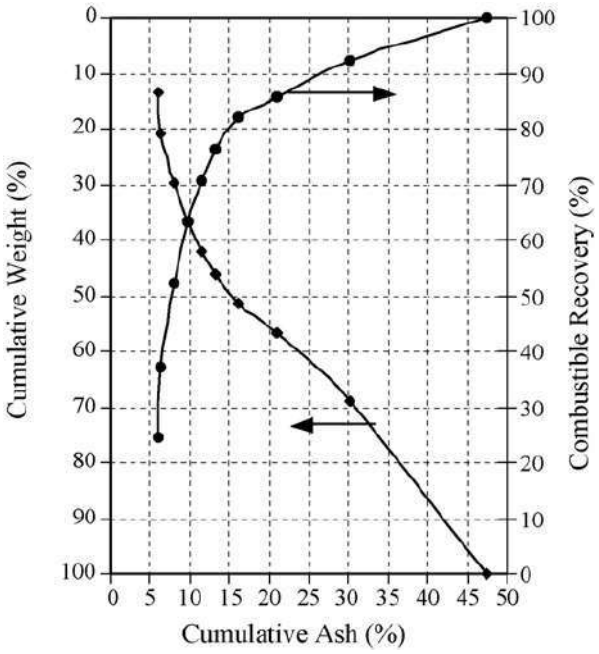


Figure 1. Column flotation cell Experimental set up



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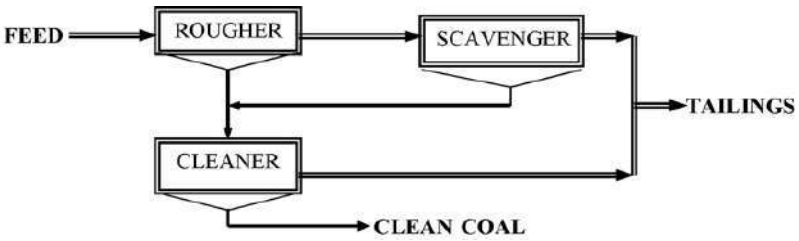

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—2.8+1.68	5.12	4.90	10.15
—1.68+0.85	6.04	19.45	10.42
—0.85+0.5	6.70	19.20	11.00
—0.5	59.27	59.14	47.95

By using release analysis calculated the affectivity of flotation which is given by Dell (1964) performed in (Fig.2).

Procedure:

One Kilo gram of coal sample was taken and added few amount of tap water was kept in conditioner tank by adding density of pulp is 10% (wt) and conditioning period is about 05 minutes. Therefore, the sample of coal was diluted uniformly with water. Then the kerosene is used as collector and MIBC as frother are added, stirred up agitating about 5 min up to required amount was obtained. Then the prepared pulp was kept into the column with speed of constant rate of feeding. The concentrate and tailing were attained in every stage of column flotation.

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The combustible recovery attained from the flotation experiments was determined by the following equation:

$$Combustible\ Recovery\ (\%) = [Wc\text{X}\ (100\text{-}A_C) / W_f\ \text{X}\ (100A_f)]\ \text{X}\ 100$$

W_c is Clean coal by weight (%). W_f is feed by weight (%). A_c is clean coal ash content by weight (%).A_f is feed ash content by weight(%).

RESULTS AND DISCUSSION:

Impact of concentration of frother

The impact of concentration of frother on flotation column was determined there are MIBC was used as frother. It has selected like frother to give the much amount of froth at various concentrations like 20 mg/l, 25 mg/l, 30 mg/l and 35 mg/l. Table 3 indicates different MIBC concentrations results at end of the tests conducted.

Table 3. Impact of concentration of frother on the flotation column.

Frother (MIBC)	Collector (Kerosene)	Frother thickness	Rate of Wash water	Air flow rate	Feeding rate	Clean coal ash	Clean coal	Combustible recovery
(mg/lt)	(g/t)	(cm)	(cm/s)	(cm/s)	(cm/s)	(%)	yield (%)	(%)
20	1200	25	0.20	2.00	0.40	20.00	41.40	63.08
25	1200	25	0.20	2.00	0.40	20.45	44.04	66.73
30	1200	25	0.20	2.00	0.40	21.25	44.56	66.84
35	1200	25	0.20	2.00	0.40	23.40	45.02	65.68

Table 4. Impact of collector on flotation column.

Collector dosage (g/t)	Frother (MIBC)	Frother thickness	Rate of Washwater	Airflowrate	Feed rate	washed coal ash	Clean coal	Combustible recovery
(ppm)		(cm)	(cm/s)	(cm/s)	(cm/s)	(%)	yield (%)	(%)
500	25	25	0.20	2.00	0.40	18.15	41.32	63.00
1000	25	25	0.20	2.00	0.40	20.55	44.30	67.04
1500	25	25	0.20	2.00	0.40	21.10	44.87	67.43
2000	25	25	0.20	2.00	0.40	22.55	44.80	65.15

Then the concentration of frother was 20 mg/l, 25 mg/l and 30 mg/l, the combustible recoveries are 62.05%, 65.33% and 65.14%, accordingly. If frother concentration enhanced about 30 mg/l, then combustible recoveries were done. Then concentration of frother about 35 mg/l, combustible recovery reduced to 64.57%. According to frother concentration, ash content of washed coal achieved to maximum value (22.30%) by mineral entrainment. Finally maximum frother concentration determined by the test results was 25mg/l.

Impact of collector dosage

In this experiment selected collector was Kerosene. The experiment has performed at different dosages of kerosene like 500 g/t, 1000 g/t, 1500 g/t, 2000 g/t were shown Table 4. When dosage of collector increased 500 g/t to 2000 g/t it shown the content of ash percentage washed coal enhanced 18.15% to 22.55%, accordingly. On other hand, enhancing the dosage of the kerosene dose not given appropriate changes about combustible recovery. Then dosage collector is around 1000 g/t 20.55% and 67.04%, are ash content and combustible recovery

of clean coal respectively. Then the maximum amount of collector noted about 1200 g/t.

Impact of frother thickness

The test was performed at different frother thicknessesd like 15 cm, 20 cm, 25 cm, 30 cm were shown Table 5. if thickness of frother increased, and then ash content and combustible recoveries of coal were decreased. The very important consideration for this is by the result of frother thickness increased, the holding time of the particles in the frother section rise up and drop back potential of gangue minerals performed with rising of water because of reduces the froth with water. According to flotation experiments, maximum value of the frother thickness was calculated as 25cm.

Impact of the rate of wash water

According to the tests conducted by the different rates of wash water 0.10 cm/s, 0.20 cm/s, 0.30 cm/s, 0.40 cm/s were shown Table 6.Finally observed content of ash from clean coal attained more rate when wash water rate less. When rate of wash water 0.1 cm/s, then clean coal ash percentage 24.82%; if this is 0.40 cm/s, 17.45% reduced. Combustible recoveries at 0.1 cm/s and 0.40 cm/s are 70.36% and 51.66%, accordingly. As per flotation test it is check out thourouly the impact of the rate of wash water on flotation test, the maximum rate of wash water was determined about 0.2cm/s.

Impact of the airflow rate

As per Table 7 the experiment carried out based on different air flow rates like 1.50 cm/s, 2.00 cm/s, 2.50 cm/s and 3.00 cm/s. Apart from this, if rate of air flow is more, due to clean coal ash content. If air flow rates are 1.50 cm/s and 3.00 cm/s, then ash contents are 20.18% and 24.22%, accordingly. Because of ash content 2 cm/s the flow rate of air disorder in the flotation process. Stabilization of froth is also in disorder.

Table 5. Impact of thickness of frother on flotation column.

Frother thickness(cm)	Frother (MIBC) (ppm)	Reagent dosage (g/t)	Rate of Wash water (cm/s)	Airflow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
15	25	1200	0.20	2.00	0.40	22.10	45.90	68.10
20	25	1200	0.20	2.00	0.40	21.45	45.08	67.44
25	25	1200	0.20	2.00	0.40	20.95	44.48	66.97
30	25	1200	0.20	2.00	0.40	19.55	40.16	61.54

Table 6. Impact of rate of wash water on flotation column .

Wash water rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Air flow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.10	25	1200	25	2.00	0.40	25.82	50.51	71.36
0.20	25	1200	25	2.00	0.40	21.46	45.11	67.48
0.30	25	1200	25	2.00	0.40	19.06	41.46	63.92
0.40	25	1200	25	2.00	0.40	17.45	33.49	52.66

Table 7. Impact of air flow rate on flotation column.

Airflow rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
1.50	25	1200	25	0.20	0.40	20.28	41.28	62.68
2.00	25	1200	25	0.20	0.40	21.35	44.90	67.26
2.50	25	1200	25	0.20	0.40	22.95	45.80	67.17
3.00	25	1200	25	0.20	0.40	25.22	47.45	67.58

Table 8. Impact of feed rate on flotation column.

Feed rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.30	25	1200	25	0.20	2.00	21.55	46.25	68.11
0.40	25	1200	25	0.20	2.00	21.82	45.90	67.35
0.50	25	1200	25	0.20	2.00	21.60	45.50	66.94
0.60	25	1200	25	0.20	2.00	21.10	43.15	63.84

Impact of the pulp rate

The different experimental values of pulp densities were shown. For various pulp densities like 0.30 cm/s 0.40 cm/s, 0.50 cm/s and 0.60 cm/s, then content of clean coal ash almost equal. The combustible recoveries are 68.11%, 67.35%, 66.94% and 63.84% for similar feed rates, accordingly. When the feed rates are high then the combustible recoveries are less. If increase feed rate which reduced holding period of particles in flotation column and coal recovery less. Due to this maximum pulp density achieved 0.40 cm/s.

Differentiation of conventional flotation cell: According to conventional flotation cell results, 5 Lts of Denver flotation column used for laboratory scale. Optimal operating variables are estimated doing the series of experiments before studies. Therefore, the exact flotation test achieved with 10% pulp density (wt) also agitating speed was 900 rpm. The collector dosage (kerosene) was used around 1000 g/t and 20ppm concentration of frother.

Firstly, single-stage flotation experiment is carried out. After that attained rougher clean coal and rougher tailing are re-fed and floated again. The circuit configuration is relatively similar to flotation column.

As per single-stage column flotation cell clean coal was attained and ash percentage was 20.55% and combustible recovery was around 67.80%, similarly the mechanical flotation cell clean coal had an ash percentage of 22.15% and a combustible recovery was around 67.72%.

Table 9. Optimal operating variables of bituminous coal

Column diameter/height	Solids ratio (%)	Frother (MIBC) (ppm)	Reagent dosage (Kerosene) (g/t)	Frother thickness(cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Feed rate (cm/s)
7/150	10	25	1200	25	0.20	2.00	0.30

Table 10. Column flotation cell results under optimum conditions

Flotation stage	Product	Ash content (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	21.55	45.37	67.80
	Tailings	69.05	54.63	32.20
Rougher–scavenger–cleaner	Clean coal	15.60	50.92	81.85
	Tailings	80.59	49.08	18.15

Table 11. Mechanical flotation cell results under optimal conditions

Stages of flotation	Product	Content of ash (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	23.15	46.95	68.72
	Tailings	69.05	53.05	31.28
Rougher–scavenger–cleaner	Clean coal	19.52	53.70	82.32
	Tailings	79.95	46.30	17.68

Therefore, discarding of ash from both flotation system are found to be 53.63% and 50.26%, accordingly.

With help of rougher–scavenger–cleaner circuit system flotation column, clean coal was attained by higher combustible recovery 80.85% and lower ash percentage of 16.60%. Inspite

of that, mechanical flotation has given the clean coal which is having combustible recovery 81.32%. Even though, the ash percentage was obtained high amount of (19.52%). Therefore, discarding the ash from both flotation system found to be 67.15% and 58.90%, accordingly.

CONCLUSIONS

1. By increasing the collector dosage which increases the flotation yield. In spite of that, the above mentioned dosage, the flotation process opposite. By addition of much amount of MIBC and frother like Kerosene, then decreases the combustible recovery slowly. In other hand clean coal of ash amount was higher. The maximum reagent dosage and frother (MIBC) contents are determined 1000 g/t and 25 mg/l, accordingly.
2. If the frother thickness increases clean coal was attained. In addition to that, if the frother level increases, flotation yield decreases. The maximum frother thickness was obtained 30 cm.
3. By addining wash water gangue minerals performed with frother then it is re washed and removed them and passing through the washed coal,by increasing the rate of wah water, clean coals are attained. Even though, at higher wash water rates, constant frother not attained then slowly decreases the yield. The maximum rate of wash water calculated about 0.20cm/s.
4. As per lower airflow rate required frother thickness couldn't achieved, thus, the yield becomes less. At high air flow rates, the yield becomes more. Even though, above at particular rate, ash content of increases enormously. Then optimal air flow rate was calculated as 2cm/s.
5. By adding more feed rate, then the flotation yield was less. In addition to that ash content in clean coal do not vary at any point. The maximum feed rate obtained was 0.30cm/s.
6. If single stage flotation process carried out in both the flotation columns, do not extract much coal. The combustible recoveries of the tailings are determined 32.20% and 31.28%, accordingly, those are comparatively more values.
7. If the tailings from rougher and rougher clean coals are continuous floated separately for rougher–scavenger–cleaner circuit, more combustible recoveries (80.85–81.32%) are attained from both of the flotation cells .Moreover, by removal of ash, then it is identified column flotation cell was most efficient. Finally, by the column flotation cell the ash percentages of the bituminous coal was decreased from 46.50% to 17.60% and yield of combustible recovery was 80.85%. With help of mechanical flotation cell ash percentage of similar coal was decreased to 20.52% and 81.32%
8. The experimental values of the column flotation cell are very near to that of release analysis values. Apart from this, column flotation cell highly efficient than the mechanical flotation cell for fine coal separation.

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Skill India
कौशल भारत-कुशल भारत

वर्ष Year 2018 पंजीकरण संख्या Regd. No. 225

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प्रमाणित किया जाता है कि श्री/सुश्री/श्रीमती This is to certify that Mr./Ms./Mrs. MEGHNA RAMAN

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पाठयक्रम में / Course परियोजना कार्य प्रशिक्षण has satisfactorily completed the Project work training

from दिनांक Dt. 15-06-2017 से to दिनांक Dt. 29-06-2017 तक सफलतापूर्वक पूर्ण किया है।

परियोजना कार्य का शीर्षक / The title of the project is STUDY OF CNC MACHINES AND PLCs

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This is to certify that **Mr. K. LOKESH KRISHNA BHARADWAJ** bearing **Reg.No: 1601-15-735-317,** a student of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY,** pursuing the Degree of **B.E.,** in Electronics and Communication Engineering, has undergone Project work/Internship titled **"DESIGN AND IMPLEMENTATION OF SMART HOME APPLICATIONS ON FPGA"** in **VLSI** under our guidance during the period from **18 May 2018** to **18 June 2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The student is punctual, hard working and shown keen interest to produce the project output and results.

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DRDL

CERTIFICATE

This is to certify that Ms. **A. Divya Teja** (Roll No. 160115735124) a third year B.E. student (Electronics & Communication Engineering) of **Chaitanya Bharathi Institute of Technology, Hyderabad** has undergone summer Internship Training at Directorate of Instrumentation, DEFENCE RESEARCH & DEVELOPMENT LABORATORY, Kanchanbagh, Hyderabad from 18-05-2018 to 26-06-2018.

Her conduct during the period of training was found to be GOOD & SATISFACTORY.

(Abhishek Singh Shakya)
Scientist 'D'
Directorate of Instrumentation
DRDL, Hyderabad

160115735122

PHONE : 040-24583040
24583151
FAX : 040-24583154

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH &
DEVELOPMENT LAB
KANCHANBAGH P.O
HYDERABAD- 500 058

NO.DRDL/DOHR/Internship/2018

DATED : 12/06/18

CERTIFICATE

This is to certify that Mr./Ms. AVANTHI BINDLA

Roll No. 160115735122 student of CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY (CBIT)

has successfully completed a miniproject titled " **A STUDY ON MISSILE TECHNOLOGY AND ITS SUB SYSTEMS**" at Defence Research & Development Laboratory (DRDL) for three weeks during May, 2018 to June, 2018.

This certificate is issued at the request of the student for academic purpose only as part of curriculum for the course of B.E/B.Tech.

(Dr. K. Rajender Rao)
Scientist F
Director, Human Resources
for Director, DRDL

068

इलेक्ट्रानिक्स कारपोरेशन आफ इण्डिया लिमिटेड
Electronics Corporation of India Limited
CIN U32100TG1967GOI001149
(भारत सरकार का उद्यम) / (A Govt. of India Enterprise)
कम्प्यूटर शिक्षा प्रभाग / COMPUTER EDUCATION DIVISION

ECIT
ISO 9001:2008

PROJECT / INTERNSHIP COMPLETION CERTIFICATE

Date: 07/07/2018

This is to certify that **Ms. S. MONIKA** bearing **Reg.No: 1601-15-735-068,** a student of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY,** pursuing the Degree of **B.E.,** in Electronics and Communication Engineering, has undergone Project work/Internship titled **"DESIGN AND IMPLEMENTATION OF SMART HOME APPLICATIONS ON FPGA"** in **VLSI** under our guidance during the period from **18 May 2018** to **18 June 2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The student is punctual, hard working and shown keen interest to produce the project output and results.

N.S.SEKHAR BABU

INCHARGE: CED

N.S. SEKHAR BABU
INCHARGE, CED, ECIL
HYDERABAD-500 062.

1601157735068

अतिथि गृह काम्प्लेकस, ई सी आई एल, हैदराबाद, तेलंगाण, भारत.
Guest House Complex, ECIL, Hyderabad - 500 062. T.S., INDIA.
दूरभाष / Tel. 2712 5864, 2712 2816, टेली फैक्स / Tele Fax : +91-040-2712 6017
वेब साइट / Web Site : www.ecil.co.in, ई-मेल / E-mail : headced@ecil.co.in

दूरभाष/Telephone 040-24584630
फैक्स/Fax
ई-मेल/E-mail

भारत सरकार, रक्षा मंत्रालय
Government of India, Ministry of Defence
रक्षा अनुसंधान एवं विकास संगठन
Defence Research & Development Organisation
उन्नत प्रणाली प्रयोगशाला
ADVANCED SYSTEMS LABORATORY
डॉ. ए.पी.जे. अब्दुल कलाम प्रक्षेपास्त्र समष्टि
Dr. A.P.J. Abdul Kalam Missile Complex
कंचनबाग डाकघर, हैदराबाद - 500 058
PO Kanchanbagh, Hyderabad - 500 058

CERTIFICATE

This is to certify that the dissertation under the title

"ARDUINO BASED DAQ SYSTEM USING LABVIEW"

is the bonafide work of

S. DIVYA SRI 160115735066

from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY as a part of Internship in the academic year 2017-18, under the guidance and supervision of Advanced Systems Laboratory, Hyderabad.

G. NAVEEN KUMAR
Scientist 'D'
जी. नवीन कुमार/G. NAVEEN KUMAR
वैज्ञानिक / SCIENTIST
रक्षा मंत्रालय, डी.आर.डी.ओ./Min. of Defence, DRDO
ए.एस.एल., हैदराबाद-58./ASL, HYDERABAD-58.

भारतीय विमानपत्तन प्राधिकरण
AIRPORTS AUTHORITY OF INDIA

Ref.AAI/ HY/ CNS/ TRG/2018/06 Dt :25-06-2018.

CERTIFICATE

This is to certify that Ms. S. Utkarsha (Reg No.160115735083) from CBIT, Hyderabad, who is studying III/IV B.Tech (Electronics & Communication Engg) has undergone Industrial Training from 01-06-2018 to 15-06-2018 in our organization. During this period, the student was familiarized with the Communication and Navigational Systems used in Hyderabad Airport.

02/7/18

(G.Satyanandam)
Jt.GM(CNS)
For GM(CIC),AAI,
Hyderabad Airport.

To
The Principal,
CBIT,
Hyderabad.

हैदराबाद हवाईअड्डा, बेगमपेट, हैदराबाद - 500016 HYDERABAD AIRPORT, BEGUMPET, HYDERABAD -500016
दूरभाष/Telephone : 040-27903785, 040-27903054 फैक्स/Fax : 040-27906001

CERTIFICATE

This is to certify that Ms. S.Utkarsha (Registration no. 160115735083), B.E (Electronics and Communication Engineering) student from Chaitanya Bharathi Institute of Technology, Gandipet , Hyderabad has successfully completed the two week (from 18 May 2018 to 3 June 2018) long internship training programme in our company.

We wish her every success in her life and career.

WABAG LIMITED

Sridhar
Chief Project Manager

Date : 16 June, 2018

WABAG
VA TECH WABAG LIMITED
CIN : L45205TN1995PLC030231
"WABAG HOUSE"
No.17, 200 Feet Thoraipakkam - Pallavaram Main Road,
Sunnambu Kolathur, Chennai - 600 117, India.
Board : +91-44-3923 2323
: +91-44-4228 2323
Fax : +91-44-3923 2324
Email : wabag@wabag.in
Web : www.wabag.com

MYTRAH

Mytrah Vayu (Sabarmati) Private Limited
(CIN : U40200TG2017PTC115612)
8001, Survey No.109, Q-City, Nanakramguda,
Gachibowli, Hyderabad - 500032, Telangana, India.
Tel. +91 40 33760100, Fax: +91 40 33760101
Website : www.mytrah.com, E-mail : mail@mytrah.com

19th July 2017

TO WHOMSOEVER IT MAY CONCERN

This is to certify that Ms. Kasim Aishwarya, a student of Electronics and Communication Engineering, Batch 2015-2019 of CBIT, Hyderabad has successfully completed her internship project on **"Vehicle Tracking Module For Wind Mast Tracking"** in our organization, from 1st June'17 to 30th June'17 as part of her curriculum.

During her internship, she was found sincere and hard working.

We wish her all the best in her future endeavors.

For Mytrah Vayu (Sabarmati) Private Limited

Ajith K N
Executive Vice President & Head- HR & FMS

इलेक्ट्रानिक्स कारपोरेशन आफ इंडिया लिमिटेड
Electronics Corporation of India Limited
CIN U32100TG1967GOI001149
(भारत सरकार का उद्यम) / (A Govt. of India Enterprise)
कम्प्यूटर शिक्षा प्रभाग / COMPUTER EDUCATION DIVISION
ECIL
ISO 9001:2008

PROJECT / INTERNSHIP COMPLETION CERTIFICATE

Date: 21/06/2018

This is to certify that **Ms. C.A.SANJANA REDDY** bearing **Reg.No: 160115735061** a student of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY, Gandipet** pursuing the Degree of **B.TECH.,** in Electronics And Communication Engineering has undergone Project work / Internship titled **"CHANGING LED COLOURS ACCORDING TO THE ACCELERATION OF THE PHONE USING A MOBILE APP"** in **"INTERNET OF THINGS"** under our guidance during the period from **24/05/2018** to **21/06/2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The student is punctual, hardworking and has shown keen interest to produce the project output and results.

N.S.SEKHAR BABU
INCHARGE: CED

N.S. SEKHAR BABU
INCHARGE, CED, ECIL
HYDERABAD-500 062.

अतिथि गृह काम्प्लेकस, ई सी आई एल, हैदराबाद, तेलंगाण, भारत.
Guest House Complex, ECIL, Hyderabad - 500 062. T.S., INDIA.
दूरभाष / Tel. 2712 5864, 2712 2816, टेली फैक्स / Tele Fax : +91-040-2712 6017
वेब साइट / Web Site : www.ecil.co.in, ई-मेल / E-mail : headced@ecil.co.in

160115735130

DEFENCE RESEARCH & DEV. LABORATORY
Ministry of Defence, GOVT OF INDIA
POST : KANCHANBAGH
HYDERABAD - 500 058 (INDIA)
DATE : 26/06/2018

D R D L

CERTIFICATE

This is to certify that Ms. **Thota Preethi** (Roll No. 160115735130) a third year B.E. student (Electronics & Communication Engineering) of **Chaitanya Bharathi Institute of Technology, Hyderabad** has undergone summer Internship Training at **Directorate of Instrumentation, DEFENCE RESEARCH & DEVELOPMENT LABORATORY**, Kanchanbagh, Hyderabad from 18-05-2018 to 26-06-2018.

Her conduct during the period of training was found to be GOOD & SATISFACTORY.

Abhishek Singh Shakya,
Scientist - 'D'
Directorate of Instrumentation
DRDL, Hyderabad-58.

(Abhishek Singh Shakya)
Scientist 'D'
Directorate of Instrumentation
DRDL, Hyderabad

1601-157-35-164

RESEARCH CENTRE IMARAT
Defence R & D Organisation
Ministry Of Defence
Vignyana Kancha – P.O.
Hyderabad – 500 069

Date: July 2nd, 2018

CERTIFICATE

This is to certify that **Mr. V SAI NIKHIL** of Chaitanya Bharathi Institute of Technology, Hyderabad has successfully completed his Summer Internship Programme during the period **25th May-30th June, 2018** with RCI (Directorate of Radar Seeker And Systems) under my guidance and supervision.

During this period he worked on "Detection of a Target Using Polyphase Codes". He also studied and familiarized with the concept of Bandpass Sampling and calculating Signal to Noise Ratio.

As per our measurements and reporting structure he is hard working and has been excellent during the internship programme. The result of this project has been found satisfactory.

We wish him all the success for his future.

Sujatha Ravichandran
Scientist 'G'
DRSS/RCI
सुजाता रविचंद्रन/Sujatha Ravichandran
वैज्ञानिक 'जी'/Scientist 'G'
निदेशक तकनीकी निदेशालय/Offic.Technology Director
Directorate of Radar Seekers & Systems (DRSS)
APJ Abdul Kalam Research Centr

1601-157-35-177

आर सी आई

ISO 9001:2008 Lab

ISO 9001 REGISTERED

RESEARCH CENTRE IMARAT
Defence R & D Organisation
Ministry Of Defence
Vignyana Kancha – P.O.
Hyderabad – 500 069

Date: July 2nd, 2018

CERTIFICATE

This is to certify that **Mr. M V N V ARUN** of Chaitanya Bharathi Institute of Technology, Hyderabad has successfully completed his Summer Internship Programme during the period **25th May-30th June, 2018** with RCI (Directorate of Radar Seeker And Systems) under my guidance and supervision.

During this period he worked on "Detection of a Target Using Polyphase Codes". He also studied and familiarized with the concept of Bandpass Sampling and calculating Signal to Noise Ratio.

As per our measurements and reporting structure he is hard working and has been excellent during the internship programme. The result of this project has been found satisfactory.

We wish him all the success for his future.

Sujatha Ravichandran
Scientist 'G'
DRSS/RCI

सुजाता रविचंद्रन/Sujatha Ravichandran
वैज्ञानिक 'जी'/Scientist 'G'
Offg. Technology Director
Directorate of Radar Seekers & Systems (DRSS)
APJ Abdul Kalam Research Centre

1601-15-735-176

RESEARCH CENTRE IMARAT
Defence R & D Organisation
Ministry Of Defence
Vignyana Kancha – P.O.
Hyderabad – 500 069

Date: July 2nd, 2018

CERTIFICATE

This is to certify that **Mr Ch Varshik** of Chaitanya Bharathi Institute of Technology, Hyderabad has successfully completed his Summer Internship Programme during the period **25th May-30th June, 2018** with RCI (Directorate of Radar Seeker And Systems) under my guidance and supervision.

During this period he worked on "Detection of a Target Using Polyphase Codes". He also studied and familiarized with the concept of Bandpass Sampling and calculating Signal to Noise Ratio.

As per our measurements and reporting structure he is hard working and has been excellent during the internship programme. The result of this project has been found satisfactory.

We wish him all the success for his future.

Sujatha Ravichandran
Scientist 'G'
DRSS/RCI

सुजाता रविचंद्रन/Sujatha Ravichandran
वैज्ञानिक 'जी'/Scientist 'G'
Directorate of Radar Seekers & Systems (DRSS)
APJ Abdul Kalam Research Centre

160115735129

इलेक्ट्रानिक्स कारपोरेशन ऑफ इण्डिया लिमिटेड
Electronics Corporation of India Limited
CIN U32100TG1967GOI001149
(भारत सरकार का उद्यम / A Govt. of India Enterprise)
कम्प्यूटर शिक्षा प्रभाग / COMPUTER EDUCATION DIVISION
ISO 9001:2008

PROJECT / INTERNSHIP COMPLETION CERTIFICATE

Date. 20/06/2018

This is to certify that **Ms. B. POOJITHA** bearing **Reg.No: 160115735129** a student of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY, Gandipet** pursuing the Degree of **B.E.,** in Electronics And Computers Engineering has undergone Project work / Internship titled **"AUTOMATIC IRRIGATION CONTROL SYSTEM"** in **"EMBEDDED SYSTEM"** under our guidance during the period from **19/05/2018** to **18/06/2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The student is punctual, hardworking and shown keen interest to produce the project output and results

N.S.SEKHAR BABU
INCHARGE: CED

N.S. SEKHAR BABU
INCHARGE, CED, ECIL
HYDERABAD-500 062.

अतिथि गृह काम्प्लेक्स, ई सी आई एल, हैदराबाद, तेलंगाण, भारत.
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वेब साइट / Web Site : www.ecil.co.in, ई-मेल / E-mail : headced@ecil.co.in

150

TESYNC™
MISSION : VALUE

Date : 01-Jun-2018

CERTIFICATE

This is to certify that **Mr. B Nikhil** student of **B.Tech (ECE)** of **Chaitanya Bharathi Institute of Technology** has successfully completed a **Summer Internship** in the areas of **C & MYSQL** from 21-May-2018 to 01-Jun-2018 under the guidance of Ms. Rohini K (Project Manager).

During the period of his Internship program with us, he had been exposed to different process was found punctual, hardworking and inquisitive.

We wish him every success in his life and career.

For Tesync Technology Limited

OVLN

OVLN Murty
Chief Technical Officer

TESYNC TECHNOLOGY LTD HYDERABAD

160115735330

भारत इलेक्ट्रॉनिक्स
भारत इलेक्ट्रॉनिक्स
BHARAT ELECTRONICS
भारत इलेक्ट्रॉनिक्स लिमिटेड
(भारत सरकार का एक उद्यम, रक्षा मंत्रालय)
आई.ई.नाचारम, हैदराबाद-500076, भारत
Bharat Electronics Limited
(A Govt. of India Enterprise, Ministry of Defence)
I.E.Nacharam, Hyderabad - 500076, India
दूरभाष Phone: +91 40 27194700, Extn:.....
फैक्स Fax: +91 40 27171406

Date: 26-06-2018

TO WHOM SO EVER IT MAY CONCERN

This is to certify that Mr Keesara Aravind(Roll No. 160115735330) BE III Year student from **Chaitanya Bharathi Institute of Technology Hyderabad** has done an intern / mini project and got the exposure in the **Electronic Warfare** (EW) equipment in NAVAL SYSTEMS Division for a period of one month from 21.05.2018 to 20.06.2018.

During those tenure at BEL, They have got the exposure on the Naval based Electronic Warfare systems . They studied one of the present EW System functionality and tested some of the sub modules of the EW System.

- ✓ Learned the Techniques used in the EW system to measure the Parameters like DOA, Frequency, PW, PRI and Amplitude.
- ✓ Learned the Hardware implementation used to measure the EW system Parameters.
- ✓ Involved in testing of Microwave components like Microwave Amplifiers, Switches, Oscillators etc.
- ✓ Got exposure in operation of various instruments like Signal Generator,, Spectrum Analyzer, CROs, Logic State Analyzer and Pulse Generator.

KURRA RAJAIAH
MANAGER (NS)
BEL, HYDERABAD

Manager (NS) / प्रबंधक (नौ.प्र)
Bharat Electronics Limited / भारत इलेक्ट्रॉनिक्स लिमिटेड
(A Govt of India Enterprise, Ministry of Defence)
(भारत सरकार का उद्यम, रक्षा मंत्रालय)
I.E. Nacharam, Hyderabad,T.S.
आई.ई.नाचारम, हैदराबाद, तेलंगाना-500076

9914 720 779 16

1601-15-735-325

दूरभाष/Telephone : 040-24584680
फैक्स/Fax
ई-मेल /E-mail

भारत सरकार, रक्षा मंत्रालय
Government of India, Ministry of Defence
रक्षा अनुसंधान एवं विकास संगठन
Defence Research & Development Organisation
उन्नत प्रणाली प्रयोगशाला
ADVANCED SYSTEMS LABORATORY
डॉ. ए.पी.जे. अब्दुल कलाम प्रक्षेपास्त्र समष्टि
Dr. A.P.J. Abdul Kalam Missile Complex
कंचनबाग डाकघर, हैदराबाद - 500 058
PO Kanchanbagh, Hyderabad - 500 058

CERTIFICATE

This is to certify that the dissertation under the title

"ARDUINO BASED DAQ SYSTEM USING LABVIEW"

is the bonafide work of

B. DIVYA 160115735325

from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY as a part of Internship in the academic year 2017-18, under the guidance and supervision of Advanced Systems Laboratory, Hyderabad.

G. NAVEEN KUMAR
Scientist 'D'
जी. नवीन कुमार/ G. NAVEEN KUMAR
वैज्ञानिक / SCIENTIST
रक्षा मंत्रालय, डी.आर.डी.ओ. / Min. of Defence, DRDO
ए.एस.एल., हैदराबाद-58. / ASL, HYDERABAD-58.

GOVERNMENT OF INDIA
RESEARCH CENTRE IMARAT
DRDO, Ministry of Defence
Vignyanakancha P.O.
HYDERABAD-500 069
☎Tel: 040-24305193

Dt: 25.04.2019

160115735178

CERTIFICATE

This is to certify that T.VISHWA TEJA (Roll No: 160115735178), Student of B.E 4th Year (E.C.E) from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY, has done project on **"Design of Slotted Waveguide Antenna for RADAR Applications"** during the period 03rd Jan 2019 to 01st Apr 2019 at Radar Seeker Laboratory, Directorate of RF Systems (DRFS), Research Centre Imarat (RCI), Hyderabad. During the training his performance has been satisfactory.

Supervisor:

25.04.2019

RAJENDER DAGGULA, SCIENTIST
Research Centre Imarat,
DRDO, Hyderabad.

राजेंदर दग्गुला/RAJENDER DAGGULA
वैज्ञानिक 'ई'/Scientist 'E'
अनुसंधान केन्द्र इमारत/Research Centre Imarat
डी आर डी ओ, रक्षा मंत्रालय, भारत सरकार
DRDO, Ministry of Defence, Govt. of India
हैदराबाद/Hyderabad-500 069.

पावर ग्रिड कारपोरेशन ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
POWER GRID CORPORATION OF INDIA LIMITED
(A Government of India Enterprise)
पावरग्रिड

एसेपाम-I क्षेत्रीय, कवाडिगुडा मेन रोड, सिकंदराबाद-500 080 (टी.एस.)
SRTS-I RHQ, Kavadiguda Main Road, Secunderabad-500 080 (T.S.)
दूरभाष Tel : 040-27546658, फैक्स Fax : 040-27546637
CIN : L40101DL1989GOI038121

160115735178

INTERNSHIP CERTIFICATE

This is to certify that Mr.T.Vishwa Teja , B.E (ECE) 3rd year, Roll No.160115735178 studying at CBIT, Hyderabad in the academic year 2017-2018, has successfully completed the Internship programme on **Optical Fiber Communication (OFC) system & OPGW cable** for one month from 01.06.2018 to 30.06.2018, during the period of internship training, his performance was found good.

Date: 30.06.2018

Place: Hyderabad

30/06/2018

डि. सुरेंदर् / D. SURENDER
मुख्य प्रबंधक/ Chief Manager (AM)
पावरग्रिड (ए.से.पा.प्र-I) / POWERGRID, (SRTS-I)
सिकंदराबाद / Secunderabad-500 080.

पंजीकृत कार्यालय: बी-9 कुतुब इंस्टीट्यूशनल एरिया, कटवारिया सराय, नई दिल्ली-110 016, दूरभाष : 011-26560112, फैक्स : 011-26601081
Registered Office: B-9, Qutub Institutional Area, Katwaria Sarai, New Delhi - 110 016. Tel. : 011-26560112, Fax : 011-26601081
केन्द्रीय कार्यालय: सौदामिनी, प्लॉट नं - 2, सेक्टर-29, गुरुग्राम-122 001 (हरियाणा) ई पी ए बी एक्स : 0124-2822000, फैक्स : 0124-2[illegible]52
Corporate Office: Saudamini, Plot No. 2, Sector-29, Gurugram-122 001 (Haryana) EPABX : 0124-2822000, Fax : 0124-25[illegible]762
Website : http://www.powergridindia.com

1601 15735 175

CERTIFICATE OF COMPLETION

This certificate is proudly presented to

B. Uma Mahesh

for completing 2 month internship programme with Plunes Technologies
as a Campus Ambassador duration **27-03-18 to 27-05-18.**
We found him sincere, hardworking, dedicated & result oriented.
He worked well as part of the team during his tenure.
We wish him all the best for his future.

Director

Plunes Technologies Pvt Ltd

For any certificate related query, please mail us at info@plunes.com

160115735175

भारत इलेक्ट्रॉनिक्स
भारत इलेक्ट्रॉनिक्स
BHARAT ELECTRONICS
भारत इलेक्ट्रॉनिक्स लिमिटेड
(भारत सरकार का एक उद्यम, रक्षा मंत्रालय)
आई.ई.नाचारम, हैदराबाद-500076, भारत
Bharat Electronics Limited
(A Govt. of India Enterprise, Ministry of Defence)
I.E.Nacharam, Hyderabad - 500076, India
दूरभाष Phone: +91 40 27194700, Extn:.....
फैक्स Fax: +91 40 27171406

Date: 26-06-2018

TO WHOM SO EVER IT MAY CONCERN

This is to certify that Mr Banakari Uma Mahesh(Roll No. 160115735175) BE III Year student from **Chaitanya Bharathi Institute of Technology Hyderabad** has done an intern / mini project and got the exposure in the **Electronic Warfare** (EW) equipment in NAVAL SYSTEMS Division for a period of one month from 21.05.2018 to 20.06.2018.

During those tenure at BEL, They have got the exposure on the Naval based Electronic Warfare systems . They studied one of the present EW System functionality and tested some of the sub modules of the EW System.

- ✓ Learned the Techniques used in the EW system to measure the Parameters like DOA, Frequency, PW, PRI and Amplitude.
- ✓ Learned the Hardware implementation used to measure the EW system Parameters.
- ✓ Involved in testing of Microwave components like Microwave Amplifiers, Switches, Oscillators etc.
- ✓ Got exposure in operation of various instruments like Signal Generator,, Spectrum Analyzer, CROs, Logic State Analyzer and Pulse Generator.

KURRA RAJAIAH
MANAGER (NS)
BEL, HYDERABAD

Manager (NS) / प्रबंधक (ना.प्र)
Bharat Electronics Limited / भारत इलेक्ट्रॉनिक्स लिमिटेड
(A Govt of India Enterprise, Ministry of De...
(भारत सरकार का उद्यम, रक्षा मंत्रालय
I.E. Nacharam, Hyderabad, T...
आई.इ.नाचारम, हैदराबाद, तेलंगाना-500...

9914 720 779 16

160115735172

PHONE : 040-24583040
24583151
FAX : 040-24583154

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH &
DEVELOPMENT LAB
KANCHANBAGH P.O
HYDERABAD- 500 058

NO.DRDL/DOHR/Internship/2018

DATED : 12/06/18

CERTIFICATE

This is to certify that Mr./Ms. A. SUKUMARAN ADARSH

Roll No. 160115735172 student of CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

has successfully completed an internship programme titled **" A STUDY ON MISSILE TECHNOLOGY AND ITS SUB SYSTEMS"** at Defence Research & Development Laboratory (DRDL) for three weeks during May, 2018 to June, 2018.

This certificate is issued at the request of the student for academic purpose only as part of curriculum for the course of B.E/B.Tech.

(Dr. K. Rajender Rao)
Scientist F
Director, Human Resources
for Director, DRDL

160115735168

GOVERNMENT OF INDIA
RESEARCH CENTRE IMARAT
DRDO, Ministry of Defence
Vignyanakancha P.O.
HYDERABAD-500 069
☎Tel: 040-24305193

Dt: 25.04.2019

CERTIFICATE

This is to certify that A. SHIVA KRISHNA (Roll No: 160115735168), Student of B.E 4th Year (E.C.E) from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY, has done project on **"Design of Slotted Waveguide Antenna for RADAR Applications"** during the period 03rd Jan 2019 to 01st Apr 2019 at Radar Seeker Laboratory, Directorate of RF Systems (DRFS), Research Centre Imarat (RCI), Hyderabad. During the training his performance has been satisfactory.

Supervisor:

25.04.2019

RAJENDER DAGGULA, SCIENTIST
Research Centre Imarat,
DRDO, Hyderabad.

राजेंदर दग्गुला/RAJENDER DA
वैज्ञानिक 'ई'/Scientist 'E'
अनुसंधान केन्द्र इमारत/Research Centre Imar
डी आर डी ओ, रक्षा मंत्रालय, भारत सरकार
DRDO, Ministry of Defence, Govt. of India
हैदराबाद/Hyderabad-500 069.

160115735168

GOVERNMENT OF INDIA
RESEARCH CENTRE IMARAT
DRDO, Ministry of Defence
Vignyanakancha P.O.
HYDERABAD-500 069
☎Tel: 040-24305193

Dt: 22.06.2018

CERTIFICATE

This is to certify that A. SHIVA KRISHNA (Roll No: 160115735168), Student of B.Tech 3rd Year (ELECTRONICS AND COMMUNICATION ENGINEERING) from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY AND SCIENCE, HYDERABAD, has done internship on **"STUDY OF ELECTROMAGNETIC FIELD EQUATIONS FOR WAVEGUIDE ANTENNA DESIGN"** during the period 15th May 2018 to 14th Jun 2018 at Radar Seeker Laboratory, Directorate of RADAR Seekers & Systems (DRSS), Research Centre Imarat (RCI), Hyderabad. During this period his performance has been satisfactory.

Supervisor:

22.06.2018

RAJENDER DAGGULA, SCIENTIST
Research Centre Imarat,
DRDO, Hyderabad.

160115735165

क्र.सं. S No. 92819

भारत डायनामिक्स लिमिटेड
BHARAT DYNAMICS LIMITED
(भारत सरकार का उद्यम A Govt. of India Enterprise)
रक्षा मंत्रालय Ministry of Defence
कंचनबाग Kanchanbagh :: हैदराबाद Hyderabad – 500058.

प्रणाली प्रौद्योगिकी तथा प्रबंधन संस्थान
INSTITUTE OF SYSTEMS, TECHNOLOGY AND MANAGEMENT

वर्ष Year 2018

Skill India

पंजीकरण संख्या Regd. No. 160

परियोजना प्रमाण-पत्र PROJECT CERTIFICATE

सुश्री / श्री
Ms. / Mr. M. SAI NIRANJAN KARTHIK

पुत्री / पुत्र श्रीमती एवं श्री
Daughter / Son of Smt. M. JAYASRI Shri M. KALYAN KUMAR

कॉलेज / संस्थान
College / Institute CHAITANYA BHARATHI INST OF TECH. ने

विषय / क्षेत्र
Subject / Discipline BE/ECE वर्ष/सेमिस्टर Year / Semester III / II में

परियोजना कार्य / प्रशिक्षण कार्य
has completed Project Work / Training on GSM BASED HOME SECURITY SYSTEM

Duration ONE MONTH Period from 24/05/2018 to 23/06/2018 में
के बीच पूर्ण किया है.

इस कार्य के दौरान इन्होंने अध्ययन में पर्याप्त रुचि दिखाई है.
He / She has shown keen interest in learning during the period of Project.

प्रमुख (मा.सं.वि.)
Head (HRD)
SYED RAFFE
अपर महाप्रबंधक (प्रशा.एवं प्रशा.) - के.बी.यू
Addl. General Manager (P&A)- KBU

मुहर
Seal

प्रभारी, परियोजना कार्य
Incharge, Project Works
वी. प्रवीन कुमार
V. PRAVEEN KUMAR
प्रबंधक (प्रशा. एवं प्रशा.) शिक्षु प्रशि एवं विधि
Manager (P&A) App. Trgs. & Legal

160115735163

GOVERNMENT OF INDIA, MINISTRY OF DEFENCE
DEFENCE RESEARCH & DEVELOPMENT LABORATORY
KANCHANBAGH, HYDERABAD-500058, A.P, (INDIA)
PHONE: (O) 91-40-24584560/4563 Fax: 91-40-24584560

A Praneeth, Sc E

Dt: 17th May 2018

CERTIFICATE OF COMPLETION

This is to certify Mr.Y.Sai Krishna Vaideek S/O Mr.Y.V.S Mahadev, a student of Electronics and Communication Engineering, Chaitanya Bharathi Institute of Technology (CBIT), Hyderabad has worked on the topic of "A New Perspective on Full Duplex Radio (FDR)" in DRDL, Hyderabad. The duration of his work was from 01/01/2018 to 01/02/2018.

He contributed in the area of self-interference cancellation in Full Duplex Radios (FDR) using MATLAB. He was able to complete the assigned task successfully in time.

During this period he demonstrated excellent technical skills in understanding the concept of FDR and simulation of self-interference cancellation in MATLAB. He is self-motivated and is eager to learn new things. His conduct during this period was found satisfactory.

A Praneeth
Scientist 'E'
A. PRANEETH / ए. प्रणीत
Scientist -'E' / वैज्ञानिक - 'ई'
Defence Research & Development Laboratory
रक्षा अनुसंधान एवं विकास प्रयोगशाला
Kanchan Bagh, Hyderabad-500 058.
कंचनबाग, हैदराबाद-500 058.

160115735163

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

July 2018

This is to certify that Mr.V.Sai Krishna Vaddeek student of Chaitanya Bharathi institute of Technology, has done a project titled "Anomaly Detection in Power Consumption Data," in the Department of Electrical Engineering, Indian Institute of Technology Hyderabad, for a period of One Month from 17th May to 18th June 2018.

Dr.P.Rajalakshmi,
Associate Professor,
Department of Electrical Engineering.

160115735162

भारत डायनामिक्स लिमिटेड
(भारत सरकार का उद्यम)
रक्षा मंत्रालय
भानूर (पी.ओ) जिलासंगारेड्डी 502305
तेलंगाना, भारत.

BHARAT DYNAMICS LIMITED
(A Govt. of India Enterprise)
MINISTRY OF DEFENCE
BHANUR (P.O), SANGAREDDY DIST. 502305
TELANGANA, INDIA.

NVT-QC AS9100 D
& ISO 9001: 2015
Certificate No: 189049-1

TO WHOMSOEVER IT MAY CONCERN

This is to certify that the Project Report on "**ASSEMBLY OPERATIONS OF AUTOMATIC CONTROL UNIT OF MISSILE LAUNCHER**" is a bonafied work carried out by **Mr. NALLANI SAI KRISHNA (160115735162)** of B.E (ECE) student of **Chaitanya Bharathi Institute of Technology, Gandipet,Hyderabad-500 075**

He is permitted for pursing an Internship Training programme at our BHARAT DYNAMICS LIMITED (BDL), Bhanur Unit from 27-June-2018 to 26-July-2018

The Internship Training programme work has been carried out by him successfully as a part of this study curriculum in partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Electronics and Communication Engineering.

The student had shown keen interest and curiosity in learning and practical applications while pursing through the project with enthusiasm. The involvement and efforts put by him is commendable during the period of Internship cum Project Work under my guidance.

I wish him a bright Career and Future.

Place: BDL,Bhanur
Date: 26-07-2018

P.HarshaVardhana Rao
Dy.Gen.Mgr(Launcher Assembly)
पी. हर्षवर्धन राव
P. HARSHA VARDHAN RAO
उप महा प्रबंधक (एल.ए)
Dy. Gen. Manager (LA)
भारत डायनामिक्स लि.
Bharat Dynamics Ltd.
भानूर, मेदक -502305
BHANUR, MEDAK-502305

160115735162

PHONE : 040-24583040
24583151
FAX : 040-24583154

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH &
DEVELOPMENT LAB
KANCHANBAGH P.O
HYDERABAD- 500 058

NO.DRDL/DOHR/Internship/2018

DATED : 12/06/18

CERTIFICATE

This is to certify that Mr./Ms. N. SAI KRISHNA

Roll No. 160115735162 student of CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY (CBIT)

has successfully completed an internship programme titled **" A STUDY ON MISSILE TECHNOLOGY AND ITS SUB SYSTEMS"** at Defence Research & Development Laboratory (DRDL) for three weeks during May, 2018 to June, 2018.

This certificate is issued at the request of the student for academic purpose only as part of curriculum for the course of B.E/B.Tech.

(Dr. K. Rajender Rao)
Scientist F
Director, Human Resources
for Director, DRDL

160115735125

CERTIFICATE OF RECOGNITION

Sunworks
energy.unlimited

STAY AHEAD.

AUTHENTICATION NO:
MM- 691

This is to certify that the Mentern **T. lakshmi Deepika** has successfully completed the Menternship **Build a Portable Solar Charger** offered by **SunWorks** in collaboration with Mentormind.in

The wind may not be in your control, but the sails are.
STAY AHEAD!

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160

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REGIONAL TELECOM TRAINING CENTRE

An ISO 9001:2008 Certified Institute
Gachibowli, Hyderabad - 500 032 Phone : 040 23000232
Fax : 040 23000229 Website : www.rttchyd.bsnl.co.in

890457

CERTIFICATE

This to certify that Mr. Battula Sai Charan Reddy *(160115735160) a student of Chaitanya Bharathi Institute of Technology has successfully completed the* "Internship Program – 2 weeks" *at Regional Telecom Training Center, Gachibowli, Hyderabad from 21-05-2018 to 01-06-2018.*

BSNL wishes him all the best for a bright future.

Place: Hyderabad
Date of Issue: 01-06-2018

Dy. General Manager
RTTC, Hyderabad

1/6/18

160115735 159

PHONE : 040-24583040
24583151
FAX : 040-24583154

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH &
DEVELOPMENT LAB
KANCHANBAGH P.O
HYDERABAD- 500 058

NO.DRDL/DOHR/Internship/2018

DATED : 12/06/18

CERTIFICATE

This is to certify that Mr./Ms. B. SAI CHARAN

Roll No. 160115735159 student of CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY

has successfully completed an internship programme titled " **A STUDY ON MISSILE TECHNOLOGY AND ITS SUB SYSTEMS**" at Defence Research & Development Laboratory (DRDL) for three weeks during May, 2018 to June, 2018.

This certificate is issued at the request of the student for academic purpose only as part of curriculum for the course of B.E/B.Tech.

(Dr. K. Rajender Rao)
Scientist F
Director, Human Resources
for Director, DRDL

158

PHONE : 040-24583040
24583151
FAX : 040-24583154

GOVERNMENT OF INDIA
MINISTRY OF DEFENCE
DEFENCE RESEARCH &
DEVELOPMENT LAB
KANCHANBAGH P.O
HYDERABAD- 500 058

NO.DRDL/DOHR/Internship/2018

DATED : 12-06-18

CERTIFICATE

This is to certify that Mr./Ms. K. RONITH RAJ

Roll No. 160115735158 student of

Chaitanya Bharathi Institute of Technology (CBIT).

has successfully completed an internship programme titled **" A STUDY ON MISSILE TECHNOLOGY AND ITS SUB SYSTEMS"** at Defence Research & Development Laboratory (DRDL) for three weeks during May, 2018 to June, 2018.

This certificate is issued at the request of the student for academic purpose only as part of curriculum for the course of B.E/B.Tech.

(Dr. K. Rajender Rao)
Scientist F
Director, Human Resources
for Director, DRDL

160115735157

क्र.सं. S.No. 92830

भारत डायनामिक्स लिमिटेड
BHARAT DYNAMICS LIMITED
(भारत सरकार का उद्यम A Govt. of India Enterprise)
रक्षा मंत्रालय Ministry of Defence
कंचनबाग Kanchanbagh :: हैदराबाद Hyderabad – 500058.

प्रणाली प्रौद्योगिकी तथा प्रबंधन संस्थान
INSTITUTE OF SYSTEMS, TECHNOLOGY AND MANAGEMENT

Skill India
कौशल भारत - कुशल भारत

वर्ष Year 2018 पंजीकरण संख्या Regd. No. 162

परियोजना प्रमाण-पत्र PROJECT CERTIFICATE

सुश्री / श्री
Ms. / Mr. R. ROHITH

पुत्री / पुत्र श्रीमती एवं श्री
Daughter / Son of Smt. S.A. BRINDA Shri R. RAMESH

कॉलेज / संस्थान
College / Institute CHAITANYA BHARATHI INST. OF TECH. ने

विषय / क्षेत्र
Subject / Discipline BE / ECE वर्ष/सेमिस्टर Year / Semester III / VI में

परियोजना कार्य / प्रशिक्षण कार्य
has completed Project Work / Training on GSM BASED HOME SECURITY SYSTEM

Duration ONE MONTH Period from 24/05/2018 to 23/06/2018 से
के बीच पूर्ण किया है.

इस कार्य के दौरान इन्होंने अध्ययन में पर्याप्त रुचि दिखाई है.
He / She has shown keen interest in learning during the period of Project.

प्रमुख (मा.सं.वि.)
Head (HRD)
सैय्यद रफी
SYED RAFFE

मुहर
Seal

प्रभारी, परियोजना कार्य
Incharge, Project Works
वी. प्रवीन कुमार
V. PRAVEEN KUMAR

अपर महाप्रबंधक (का. एवं प्रशा.) - केबीयू
Addl. General Manager (P&A)- KBU

प्रबंधक (का. एवं प्रशा.) शिक्षु प्रशि एवं विधि
Manager (P&A) App. Trgs. & Legal

153

TESYNC
MISSION : VALUE

Date : 01-Jun-2018

CERTIFICATE

This is to certify that **Mr. P Nirnay Reddy** student of **B.Tech (ECE)** of **Chaitanya Bharathi Institute of Technology** has successfully completed a Summer Internship in the areas of **C & MYSQL** from 21-May-2018 to 01-Jun-2018 under the guidance of Ms. Rohini K (Project Manager).

During the period of his Internship program with us, he had been exposed to different process was found punctual, hardworking and inquisitive.

We wish him every success in his life and career.

For Tesync Technology Limited

OVLN

TESYNC TECHNOLOGY LTD HYDERABAD 1/6/18

OVLN Murty
Chief Technical Officer

TESYNC
MISSION : VALUE

160115735-152

Date : 01-Jun-2018

CERTIFICATE

This is to certify that Mr. M Nikhil student of B.Tech (ECE) of Chaitanya Bharathi Institute of Technology has successfully completed a Summer Internship in the areas of C & MYSQL from 21-May-2018 to 01-Jun-2018 under the guidance of Ms. Rohini K (Project Manager).

During the period of his internship program with us, he had been exposed to different process was found punctual, hardworking and inquisitive.

We wish him every success in his life and career.

For Tosync Technology Limited

OVLN

OVLN Murty
Chief Technical Officer

160115735147

Govt. of India
Ministry of Defence
DEFENCE RESEARCH & DEV. ORGN.
DEFENCE RESEARCH & DEV.
LABORATORY
PO: KANCHANBAGH
HYDERABAD – 500 058
Ph.040-24583041 Fax No.040-24585019

Lr. No. DRDL/PROJECT/2018

DATED: 25 June 2018

CERTIFICATE

This is to certify that as part of his curriculum in B. Tech (ECE), **Mr. K MAHIDHAR (Roll No.160115735147)** student of CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY College has successfully completed his **Internship** at Defence Research & Development Laboratory (DRDL).

During the period from **28.05.2018** to **25.06.2018**, He was found to be Sincere & Hard working and also took keen interest in the areas related to the Project.

(D. SUNEETHA)
Sc 'E'
DRDL, HYDERABAD

DARA SUNEETHA
SCIENTIST
MIN.OF DEFENCE, GOVT.OF INDIA
DRDL, HYDERABAD-58.

160115735145

क्र.सं. S.No. 92820

भारत डायनामिक्स लिमिटेड
BHARAT DYNAMICS LIMITED
(भारत सरकार का उद्यम A Govt. of India Enterprise)
रक्षा मंत्रालय Ministry of Defence
कंचनबाग Kanchanbagh :: हैदराबाद Hyderabad – 500058.

प्रणाली प्रौद्योगिकी तथा प्रबंधन संस्थान
INSTITUTE OF SYSTEMS, TECHNOLOGY AND MANAGEMENT

Skill India

वर्ष Year 2018 पंजीकरण संख्या Regd. No. 161

परियोजना प्रमाण-पत्र PROJECT CERTIFICATE

सुश्री / श्री
Ms. / Mr. MANTHRIPRAGADA JAYA MAHEEDHAR

पुत्री / पुत्र श्रीमती एवं श्री
Daughter / Son of Smt. M. YOGITA Shri M. VEERA RAGHAVA RAO

कॉलेज / संस्थान ने
College / Institute CHAITANYA BHARATHI INST. OF TECHNOLOGY

विषय / क्षेत्र वर्ष/सेमिस्टर में
Subject / Discipline BE / ECE Year / Semester III / VI

परियोजना कार्य / प्रशिक्षण कार्य
has completed Project Work / Training on GSM BASED HOME SECURITY SYSTEM

से
Duration ONE MONTH अवधि Period from 24/05/2018 to 23/06/2018
के बीच पूर्ण किया है.

इस कार्य के दौरान इन्होंने अध्ययन में पर्याप्त रुचि दिखाई है.
He / She has shown keen Interest In learning during the period of Project.

प्रमुख (मा.सं.वि.)
Head (HRD)
SYED RAFFE
अपर महाप्रबंधक (का. एवं प्रशा.) - के.बी.यू.
Addl. General Manager (P&A)- KBU

मुहर Seal

प्रभारी, परियोजना कार्य
Incharge, Project Works
वी. प्रवीन कुमार
V. PRAVEEN KUMAR
प्रबंधक (का. एवं प्रशा.) शिक्षु प्रशि एवं. विधि
Manager (P&A) App. Trgs. & Legal

142

TESYNC™
MISSION : VALUE

Date : 01-Jun-2018

CERTIFICATE

This is to certify that **Mr. A Amit Kumar Jain** student of **B.Tech (ECE)** of **Chaitanya Bharathi Institute of Technology** has successfully completed a Summer Internship in the areas of **C & MYSQL** from 21-May-2018 to 01-Jun-2018 under the guidance of Ms. Rohini K (Project Manager).

During the period of his Internship program with us, he had been exposed to different process was found punctual, hardworking and inquisitive.

We wish him every success in his life and career.

For Tesync Technology Limited

OVLN

OVLN Murty
Chief Technical Officer

TESYNC TECHNOLOGY LTD HYDERABAD

GOVERNMENT OF INDIA
RESEARCH CENTRE IMARAT
DRDO, Ministry of Defence
Vignyanakancha P.O.
HYDERABAD-500 069
☎ Tel: 040-24305193

Dt: 22.06.2018

160115735144

CERTIFICATE

This is to certify that K. HANUMANTHU (Roll No: 160115735144), Student of B.Tech 3rd Year (ELECTRONICS AND COMMUNICATION ENGINEERING) from CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY AND SCIENCE, HYDERABAD, has done internship on **"STUDY OF ELECTROMAGNETIC FIELD EQUATIONS FOR WAVEGUIDE ANTENNA DESIGN"** during the period 15th May 2018 to 14th Jun 2018 at Radar Seeker Laboratory, Directorate of RADAR Seekers & Systems (DRSS), Research Centre Imarat (RCI), Hyderabad. During this period his performance has been satisfactory.

Supervisor:

22.06.2018

RAJENDER DAGGULA, SCIENTIST
Research Centre Imarat,
DRDO, Hyderabad.

160115735144

MEDHA®

Ref.: MSDPL/MTC/STD PROJ/2017/42

10.June.2017

To

Head of the Department,

ECE Department,

Chaitanya Bharathi Institute of Technology

Gandipet,

Hyderabad.

Dear Sir/Madam,

Sub: Certificate - Completion of Internship.

I am pleased to certify that your student Mr. Hanumanthu K (R.No 160115735144) from II/II, B. E – Electronics & Communication Engineering, has successfully completed the Internship from 29.May.17 to 10.June.17.

We hope this activity has been useful to him and he has enhanced his skill set.

K.Saty

Thanks and Regards,

Satyanarayana K

Manager – Training.

MEDHA SERVO DRIVES PVT. LTD. * HYDERABAD

aqa INTERNATIONAL NABCB QM014

ISO 9001 Certified

MEDHA SERVO DRIVES PVT. LTD.

Regd. Office : P-4/5B, Industrial Park, Nacharam, Hyderabad - 500 076, A.P.
Ph : +91-40-67237000/67237001/9885190083 Fax No.+91-40-67237081, Email : info@medhaindia.com

Works : Jodimetla Cross Road, Korremula (Vill), Ghatkesar (M), R.R.Dt., A.P. 500088
Ph :+91-40-67237999/9885190038 Fax No. +91-40-67237898 URL :http://www.medhaindia.com

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INSTITUTE OF SYSTEMS, TECHNOLOGY AND MANAGEMENT

Skill India

वर्ष Year 2018 पंजीकरण संख्या Regd. No. 159

परियोजना प्रमाण-पत्र PROJECT CERTIFICATE

सुश्री / श्री
Ms. / Mr. S. AJITH KUMAR

पुत्री / पुत्र श्रीमती एवं श्री
Daughter / Son of Smt. S. RAJITHA Shri S. VISHWA PRASAD

कॉलेज / संस्थान ने
College / Institute CHAITANYA BHARATHI INST. OF TECH.

विषय / क्षेत्र वर्ष/सेमिस्टर में
Subject / Discipline BE / ECE Year / Semester III / II

परियोजना कार्य / प्रशिक्षण कार्य
has completed Project Work / Training on GSM BASED HOME SECURITY SYSTEM

Duration ONE MONTH Period from 24/05/2018 से to 23/06/2018
के बीच पूर्ण किया है.

इस कार्य के दौरान इन्होंने अध्ययन में पर्याप्त रुचि दिखाई है.
He / She has shown keen interest in learning during the period of Project.

प्रमुख (मा.सं.वि.)
Head (HRD)
SYED RAFFE

मुहर
Seal

प्रभारी, परियोजना कार्य
Incharge, Project Works
वी. प्रवीन कुमार
V. PRAVEEN KUMAR

अपर महाप्रबंधक (प्र. एवं प्रशा.) के.बी.यू.
Addl. General Manager (P&A)- KBU

Manager (P&A) App. Trgs. & Legal

BHARAT SANCHAR NIGAM LIMITED

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REGIONAL TELECOM TRAINING CENTRE

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Gachibowli, Hyderabad - 500 032 Phone : 040-23000232
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82B0509

CERTIFICATE

This is to certify that Mr. Burgula Ranjith Kumar /160114735045/ student of Chaitanya Bharathi Institute of Technology, pursuing B.E, has successfully completed the Inplant Training in "Basic Telecom" at Regional Telecom Training Center, BSNL, Gachibowli, Hyderabad, from 11-06-2018 to 23-06-2018.

His Performance during this training has been Excellent.

BSNL wishes him all the best for a bright future.

Place: Hyderabad
Date: 23-06-2018

General Manager ★ R.T.T.C., BSNL ★ Hyderabad.

Dy. General Manager
RTTC, Hyderabad
23.6.18

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భారత్ హెవీ ఎలెక్ట్రికల్స్ లిమిటెడ్

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भारत हेवी इलेक्ट्रिकल्स लिमिटेड

हेवी पावर इक्विपमेंट प्लांट, रामचन्द्रापुरम, हैदराबाद - 502032 (भारत)

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Human Resource Development Centre

बीएचईएल पंजीयन संख्या / BHEL Reg. No. 150N6041246 दिनांक / Date: 19/06/2018

प्रोजेक्ट कार्य प्रशिक्षण प्रमाण पत्र

PROJECT WORK TRAINING CERTIFICATE

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प्रोजेक्ट प्रशिक्षण प्रभारी

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Addl. Engineer/HRDC WIS
B.H.E.L, HYD-32.

इलक्ट्रानिक्स कारपारशन आफ इण्डया लिमटड
Electronics Corporation of India Limited
CIN U32100TG1967GOI001149
(भारत सरकार का उद्यम) / (A Govt. of India Enterprise)
कम्प्यूटर शिक्षा प्रभाग / COMPUTER EDUCATION DIVISION
ISO 9001:2008

PROJECT / INTERNSHIP COMPLETION CERTIFICATE

Date: 27/06/2018

This is to certify that **Mr. BOORLA PAVAN KUMAR** bearing **Reg.No: 1601-15-735-307,** a student of **CHAITANYA BHARATHI INSTITUTE OF TECHNOLOGY,** pursuing the Degree of **B.E.,** in Electronics and Communication Engineering, has undergone Project work/Internship titled **"DESIGN AND IMPLEMENTATION OF SMART HOME APPLICATIONS"** in **VLSI** under our guidance during the period from **28 May 2018** to **27 June 2018** in partial fulfillment of the requirements for the award of the above mentioned Degree. The student is punctual, hard working and shown keen interest to produce the project output and results.

N.S SEKHAR BABU

INCHARGE: CED

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ORIGINAL CONTRIBUTION

Optimal Contractor Selection in Construction Industry: The Fuzzy Way

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Abstract A purely price-based approach to contractor selection has been identified as the root cause for many serious project delivery problems. Therefore, the capability of the contractor to execute the project should be evaluated using a multiple set of selection criteria including reputation, past performance, performance potential, financial soundness and other project specific criteria. An industry-wide questionnaire survey was conducted with the objective of identifying the important criteria for adoption in the selection process. In this work, a fuzzy set based model was developed for contractor prequalification/evaluation, by using effective criteria obtained from the percept of construction professionals, taking subjective judgments of decision makers also into consideration. A case study consisting of four alternatives (contractors in the present case) solicited from a public works department of Pondicherry in India, is used to illustrate the effectiveness of the proposed approach. The final selection of contractor is made based on the integrated score or Overall Evaluation Score of the decision alternative in prequalification as well as bid evaluation stages.

Keywords Contractor evaluation · Fuzzy Set Theory · Prequalification · Selection criteria · Overall Evaluation Score

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Introduction

Project construction must be managed in an effective manner considering the growing demand from clients, competition, and regulatory agencies [1]. However, a failure to properly manage these challenges can lead to problems for the entire project and construction team as well. One of the potential risks in construction projects is the selection of unsuitable contractors which have a considerable impact on client goals such as financial resources, cost, quality, project duration and increasing chances of project success [2]. Thus, contractor selection is viewed as a multifaceted decisive problem in the process of construction management due to the involvement of number of criteria and their interdependence. Therefore, the capability of the contractor to implement the project should be evaluated using a multiple set of selection criteria including reputation, past performance, performance potential, financial soundness and other project specific criteria [3]. Generally, clients tend to select contractors purely on the basis of lowest bid price although tender conditions stipulate several other evaluation criteria. Some researchers opined that contractors should not be selected based on lowest price, but it should be attributed to the highest weight in view of the involved project delivery problems [4]. Both the selected criteria and a sound evaluation methodology are essential for contractor selection, including prequalification, in order to guarantee the simultaneous achievement of time, cost, and quality specifications [2]. Further, contractor selection is a group decision making process under multiple criteria wherein human judgment and crisp data are not adequate to model human preferences with an exact numerical value. Hence, a more realistic approach may be to use linguistic assessments instead of numerical values. Therefore, the ratings

and weights of criteria in the problem are to be assessed by means of linguistic variables, which are useful in dealing with too complex or ill-defined situations [3, 5]. Thus, Fuzzy set based approach that makes use of linguistic variables and has the advantage of simultaneously considering multiple criteria, multiple decision makers and handling vague and imprecise data. This paper outlines a Fuzzy Set Theory (FST) based methodology, for optimal contractor selection, to handle the uncertainty involved in decision making.

Literature Review

Different researchers and client organizations used varying sets of contractor selection criteria to assess the capability of the candidate contractors [6]. Russell et al. [7] have considered financial stability, past performance, experience, and key personnel availability as selection criteria. Holt et al. [8, 14] considered contractor's current workload, past experience in terms of size of projects completed, management resources in terms of formal training regime, past performance and time of year weather; whereas Hatush and Skitmore [9, 15] used financial soundness, technical ability, management capability, and health and safety performance as Contractor selection criteria. Waara and Bröchner [10] investigated the Price and Non price Criteria for Contractor Selection. Krishna Rao et al. [11] conducted a questionnaire survey with construction professionals of the Indian construction industry and proposed criteria set for contractor evaluation in the Indian context. A few researchers worked on contractor selection and proposed different methodologies for bid evaluation [12]. Nguyen [13] proposed a model based on fuzzy sets to tender evaluation. Holt et al. [8, 14] provided example application of multi-attribute analysis (MAA) to the evaluation of construction bidders. Hatush and Skitmore [9, 15] applied program evaluation and review technique (PERT) to evaluate contractor data against client goals (time, cost and quality). Russell et al. [16] developed a rule-based expert system called 'Qualifier-2' for contractor pre-qualification while Sonmez et al. [17] adopted evidential reasoning theory to prequalify contractors. McCabe et al. [18] established a contractor prequalification model using data envelopment analysis (DEA). Hanna et al. [19] and Lam et al. [20] applied neural networks to contractor prequalification. Singh and Tiong [21, 22] identified contractor selection criteria (CSC) relevant to Singapore construction industry and developed a fuzzy decision framework for contractor selection. Morote and Ruz-Vila [23] illustrated the use of a systematic prequalification procedure, based on Fuzzy Set Theory, for evaluation of five contractors for the rehabilitation project of a building at Technical University of Cartagena. Krishna Rao et al. [24] proposed multiplicative approach of multi-attribute utility theory for contractor Prequalification and illustrated the same considering the case study of construction of a multistoried building. Paul et al. [25] compared the contractor selection process using TOPSIS and Extended TOPSIS models. Krishna Rao [26] pointed out that the current contractor selection system awards the contract to the prequalified contractor having the lowest bid price, ignoring the contractor's merit in prequalification score. A modification to the present system, combining the prequalification score and bid price score was suggested by Krishna Rao [26], for the final selection of the contractor in his proposed fuzzy set based approach.

A comprehensive literature review revealed that there is a need to select a potential contractor based on a set of multiple decision criteria, both price and non-price related and evolve a method that considers group decision making. The contractor selection should be made in two—stages viz; (1) Prequalification—examining the contractors for the desired minimum requisites of project implementation, and (2) Evaluation of selected price bids of contractors. Traditional models of contractor evaluation lean to ignore vagueness, fuzziness and human behaviour inherent in the very nature of construction projects.

Research Significance

The concept of integrating prequalification/technical score with bid price score is gaining popularity for selecting an optimal contractor to enable the owners/clients to successfully complete the projects in terms of time, cost and quality. The present work addresses this aspect using Fuzzy Set Theoretic approach for the selection of the contractor. In the present work, this methodology is demonstrated through a case study considering 15 contractor selection criteria (CSC), excepting bid price. Further, relative priority values of criteria are worked out based on the perceptions of construction professionals (Contractors, Public and Private Clients), along with the criteria preferences of Decision Makers (DMs) employed for contractor evaluation in order that the selection process becomes more effective in realizing its objective in true sense. In this method, decision makers evaluate the fuzzy weights of the criteria and contractors assessment on a particular criterion using linguistic variables to consider the uncertainty associated with the mapping of human perception to a numerical value.

Fuzzy Set Approach to Decision Making

Linguistic Variables and Membership Function

The fuzzy set is a kind of mathematical expression which deals with some phenomenon with vagueness.

A mapping on the Universe X can be given as

$$\mu_A : X \rightarrow [0, 1] \quad (1)$$

$$x \rightarrow \mu_A(x) \quad (2)$$

where, μ_A represents a fuzzy subset A on the Universe with μ_A as the membership of A, and $\mu_A(x)$ as the grade of membership. The membership grades are very often represented by real-number values ranging in the closed interval between 0 and 1. The grade of membership is usually expressed in terms of trapezoidal and triangular membership functions.

The fuzzy set provides the concepts of membership function, linguistic variables, and so on for describing a vague concept. The decision makers can evaluate the criteria or alternatives in terms of linguistic variables such as Very Important/Very Good, Good/Important, Above Average, Average, Below Average, poor and very Poor. For each linguistic variable, there is a corresponding fuzzy number.

Fuzzy Weights Calculation

The average Fuzzy weights can be calculated according to the fuzzy number of each linguistic variable. Let $A = \{a_1, a_2, a_3, a_4\}$, $B = \{b_1, b_2, b_3, b_4\}$ be any two positive trapezoidal fuzzy numbers and $\oplus$ is the symbol for fuzzy plus operation, then fuzzy plus operation (fuzzy addition) is expressed as:

$$\begin{aligned} A \oplus B &= \{a_1, a_2, a_3, a_4\} + \{b_1, b_2, b_3, b_4\} \\ &= \{a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4\} \end{aligned} \quad (3)$$

The average fuzzy weight is the arithmetical average of all fuzzy weights for factor C_{ij} given by all decision makers which can be expressed as

$$A_{ij} = \{a_{ij}, b_{ij}, c_{ij}, d_{ij}\} \quad (4)$$

where, $a_{ij} = \frac{\sum_{k=1}^{P} ak}{P}$, $b_{ij} = \frac{\sum_{k=1}^{P} bk}{P}$, $c_{ij} = \frac{\sum_{k=1}^{P} ck}{P}$ and $d_{ij} = \frac{\sum_{k=1}^{P} dk}{P}$ i = 1, 2 …n and j = 1, 2…m.

A_{ij}^{k} represents the fuzzy weight assigned to factor C_{ij} by expert/decision maker, k;

$A_{ij} = \{a_{ij}, b_{ij}, c_{ij}, d_{ij}\}$ represents the average fuzzy weight assigned to factor C_{ij}; and P represents the number of decision makers involved in the process.

Defuzzification

Defuzzification is an operation of producing a crisp value that adequately represents the degree of satisfaction of the aggregated fuzzy number. For a trapezoidal membership function, the defuzzified value, e_{ij} for the average fuzzy weight of factor C_{ij} is given by the following equation

$$e_{ij} = (aij + bij + cij + dij)/4 \quad (5)$$

where e_{ij} represents the defuzzified value for the average fuzzy weight of factor, C_{ij}.

The defuzzified values are normalized and the weight of factor, C_{ij} is obtained by using the following equation.

$$\mu(C_{ij}) = \frac{eij}{\sum eij} \quad (6)$$

where, $\mu(C_{ij})$ represents weight of factor, C_{ij}.

Optimal Contractor Selection

In the present study as explained above the Fuzzy Set Theory is used for the selection of an optimal contractor. A real case of construction of a multi-storey building for housing quarters, located in Pondicherry in India, with an estimated contract value (ECV) of INR 360,000,000 is considered in this paper. The project completion time is 25 months. Four bidders namely Contractor P, Contractor Q, Contractor R and Contractor S have participated in tendering process. The bid prices quoted by contractors **P**, **Q**, **R** and **S** for the project under consideration are INR 363,223,423; INR 389,243,765; INR 426,798,887; and INR 385, 678,459 respectively.

Identification of Contractor Selection Criteria (CSC)

An initial list of 108 criteria, apart from tender price, was selected from the published literature and on the basis of popularity of their use in the context of UK, USA, Hong Kong, Australia, Singapore and Indian Construction industries. In order to identify the significant criteria for contractor selection in Indian context, ten experienced construction practitioners, experienced in tender evaluation exercise, from public and private sectors were involved. Based on their input, 68 contractor selection criteria (CSC), covering 6 main criteria, were chosen for inclusion in the final version of the questionnaire. The relevant and important CSC, in addition to tender price, selected from preliminary round of interviews were categorized into **A** Contracting Company's attributes, **B** Experience record, **C** Past performance of the contractor, **D** Financial

capability of the contractor, **E** Performance potential of the contractor and **F** Project specific criteria. Respondents were asked to indicate their opinion, on the level of importance of criteria in assessing the capabilities of the contractor, on a six-point Likert scale (0–5). The 68 criteria of the questionnaire included in the "Appendix" were weighed by experienced construction practitioners, ranging from public to private sectors, based on the scale mentioned. The questionnaire data were analyzed on the basis of Relative Rank Index (RRI) or Relative Importance Index (RII) technique [27, 28]. In the present study, the top 15 criteria having RRI value more than 0.80, obtained from the ALL respondent perception i.e. Perceptions of 3 groups of respondents (public clients, private clients and contractors) taken together, are considered for the contractor evaluation process as it reflects the polarized view point of respondents. Those top 15 criteria with RRI > 0.8, the bench mark adopted for deciding the significant criteria, are considered to be significant in contractor evaluation and the same are enlisted in Table 1. Therefore, the criteria set shown in Table 1 could be adopted for use in contractor evaluation [11].

Contractor Prequalification using Fuzzy Set Theoretic Approach

In the fuzzy set based model for contractor Prequalification/selection, the linguistic variables are used by decision makers to evaluate the fuzzy weights of the criteria and contractors on a particular criterion. The linguistic variables and the corresponding fuzzy numbers for the trapezoidal membership function (Fig. 1) chosen by the decision maker, to evaluate the importance of the criteria and the ratings of contractor alternatives with respect to qualitative criteria are as presented in Table 2. Three decision makers DM-1, DM-2 and DM-3 were employed to evaluate the candidate contractors on the criteria considered, using the linguistic variables shown in Table 2. Tables 3, 4, 5, 6, 7, 8, 9 and 10, explain the fuzzy evaluation of criteria, calculation and ranking of prequalified contractors by calculating the crisp score of the decision alternatives (contractors in this case).

The decision makers' preferences, in respect of various main criteria (A–F) and the decision alternatives (contractors), expressed in linguistic variables are presented in Tables 3 and 6 (decision- makers' fuzzy evaluation of importance of criteria and contractors) respectively. The linguistic variables assigned to criteria are then converted into corresponding fuzzy numbers as shown in Table 3.

To normalize the differences existing in different decision makers' preferences on a criterion or a decision alternative (contractor in this context), a simple average of fuzzy numbers (average fuzzy score) is calculated to subsequently determine the weights or priorities. The average fuzzy scores for the main criteria and decision alternatives are calculated using Eq. 4 and are shown in Tables 4 and 7 respectively. After determining the average fuzzy score, defuzzification is done using Eq. 5, to obtain the defuzzified or the crisp values for various main criteria as shown in Table 4.

From the defuzzified values of main criteria, normalized crisp scores or normalized crisp values have been computed using Eq. 6 and are also presented in Table 4.

Table 1 Contractor Selection/Evaluation Criteria (with RRI > 0.80)

Main criteria		Sub-criteria	
A	Contracting company's attributes	A1	Age (experience), registration of contractor's firm
B	Experience record	B1	Experience of working on similar projects
		B5	Type and size of past projects
C	Past performance of the contractor	C1	Work quality in completed projects
		C2	Adherence to time schedule in past works
		C11	Blacklisting in past projects
		C12	Quality of service during defect- liability period
D	Financial capability of the contractor	D1	Current commitments
		D6	Turnover
E	Performance potential of the contractor	E3	Availability of plant and equipment resources
		E4	Present workload and capability to support the current project
		E5	Quality control and assurance program
		E6	Specialized knowledge of construction method
F	Project specific criteria	F2	Specified project time schedule
		F4	Qualification, experience of professional and technical staff

Table 2 Linguistic variables and fuzzy numbers for rating criteria and contractor

Linguistic variables for rating				Fuzzy numbers
Criteria		Contractor		
VI	Very important	VG	Very good	(0.8, 0.9, 1.0, 1.0)
I	Important	G	Good	(0.6, 0.7, 0.8, 0.9)
MHI	Moderate high importance	AA	Above average	(0.5, 0.6, 0.7, 0.8)
MI	Moderate importance	A	Average	(0.4, 0.5, 0.5, 0.6)
MLI	Moderate low importance	BA	Below average	(0.2, 0.3, 0.4, 0.5)
LI	Low important	P	Poor	(0.1, 0.2, 0.3, 0.4)
VLI	Very low important	VP	Very poor	(0.0, 0.0, 0.1, 0.2)

Table 5 shows the Relative importance of sub criteria that is worked out by integrating the preferences of DMs considered in the present work i.e. Priority ($\mathbf{P}_i$) of main criterion and the Relative Rank/Importance Index (RRI/RII) of sub-criterion ($\mathbf{r}_i$) obtained from the questionnaire survey conducted with Construction professionals, i.e. Contractors, Public and private clients in Construction Industry [26]. Tables 6 and 7 show the details of the decision makers' evaluation and the average fuzzy scores of the contractors.

Tables 8 and 9 respectively show the defuzzified values (crisp scores) and the normalized defuzzified values of contractor assessment (calculated using Eqs. 5 and 6 respectively). Normalized defuzzified values provide the priority of criterion and of the alternative (contractor in this case) for the criterion under consideration.

In the final step of the process, numerical priorities in terms of the Overall Priority Values (OPV) that represent the alternatives' relative ability to achieve the decision goal are obtained for each of the decision alternatives. The Overall Priority Values of contractor (Table 10) are obtained by sum product of the criterion priority and the contractor priority for a particular alternative. The pre-qualified contractors are ranked based on overall priority value (OPV) and a contractor with the highest OPV is Ranked-1 and so on. From the Overall priority values (OPV) of contractors computed in Table 10, using criterion RRI values of ALL respondents' percept, the rank order of the four prequalified contractors **P**, **Q**, **R** and **S**, based on prequalification/Technical score is **4–2–3–1**.

Final Selection of Contractor

In the preceding part, the prequalified contractors have been ranked based on their technical potential (prequalification score), excepting the quoted bid price. It is generally

Table 3 Decision makers fuzzy evaluation of importance of main criteria

Criterion	Linguistic variables			Fuzzy numbers		
	DM-1	DM-2	DM-3	DM-1	DM-2	DM-3
A	LI	LI	MI	(0.1, 0.2, 0.3, 0.4)	(0.1, 0.2, 0.3, 0.4)	(0.4, 0.5, 0.5, 0.6)
B	VI	VI	I	(0.8.0.9, 1.0, 1.0)	(0.8.0.9, 1.0, 1.0)	(0.6, 0.7, 0.8, 0.9)
C	MHI	MHI	MI	(0.5, 0.6, 0.7, 0.8)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)
D	I	I	VI	(0.6, 0.7, 0.8, 0.9)	(0.6, 0.7, 0.8, 0.9)	(0.8.0.9, 1.0, 1.0)
E	MI	MI	MHI	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.5, 0.6, 0.7, 0.8)
F	MLI	MLI	MLI	(0.2, 0.3, 0.4, 0.5)	(0.2, 0.3, 0.4, 0.5)	(0.2, 0.3, 0.4, 0.5)

Table 4 Fuzzy calculations for main criteria

Criterion	Average fuzzy score	Crisp score	Normalized crisp score
A	(0.2, 0.3, 0.366, 0.466)	0.333	0.095
B	(0.733, 0.833, 0.933, 0.966)	0.86625	0.2471
C	(0.466, 0.566, 0.633, 0.733)	0.5995	0.171
D	(0.666, 0.766, 0.866, 0.933)	0.80775	0.2304
E	(0.433, 0.533, 0.566, 0.666)	0.5495	0.1567
F	(0.2, 0.3, 0.4, 0.5)	0.35	0.0998

Table 5 Relative importance of sub criteria—ALL respondents

Criterion	Priority (P_i)	Sub-criterion	RRI value of ALL respondents (r_i)	Normalized RRI value Ri = (r_i/$\sum r_i$)	Relative importance of sub-criterion (P_i*Ri)
A	0.095	A1	0.808	1	0.094
B	0.247	B1	0.892	0.521	0.1293
		B5	0.82	0.479	0.1188
C	0.171	C1	0.832	0.2412	0.0415
		C2	0.866	0.2512	0.0432
		C11	0.913	0.2648	0.0455
		C12	0.837	0.2427	0.0417
D	0.23	D1	0.808	0.4879	0.1122
		D6	0.848	0.5121	0.1177
E	0.156	E3	0.824	0.248	0.0388
		E4	0.833	0.2507	0.0392
		E5	0.852	0.2564	0.0401
		E6	0.814	0.245	0.0383
F	0.099	F2	0.856	0.5086	0.0508
		F4	0.83	0.4914	0.0491

Table 6 Decision makers fuzzy evaluation of contractors

Criterion/contractor	DM1				DM2				DM3			
	P	Q	R	S	P	Q	R	S	P	Q	R	S
A1	G	VG	AA	AA	G	G	G	AA	G	G	AA	AA
B1	VG	BA	G	AA	VG	A	AA	AA	G	A	AA	AA
B5	BA	A	G	VG	A	AA	G	VG	BA	AA	G	VG
C1	A	A	A	A	A	A	A	A	A	A	A	A
C2	A	AA	G	G	A	AA	AA	VG	A	AA	AA	G
C11	VG	VG	VG	A	VG	VG	VG	A	VG	VG	VG	BA
C12	A	A	A	A	A	A	A	A	A	A	A	A
D1	AA	AA	A	G	AA	AA	A	G	AA	AA	A	G
D6	A	G	BA	G	A	G	BA	G	A	G	BA	G
E3	AA	VG	VG	VG	AA	VG	VG	VG	AA	VG	VG	VG
E4	A	A	A	A	A	A	A	A	A	A	A	A
E5	BA	VG	VG	G	BA	G	VG	G	BA	VG	VG	VG
E6	A	A	A	A	A	A	A	A	A	A	A	A
F2	A	A	A	A	A	A	A	A	A	A	A	A

observed that any prequalified contractor having the lowest bid price wins the contract, which underlines the contradiction of not taking the first stage prequalification scores into account in second stage evaluation (price bid evaluation) as the winner may also have the lowest prequalification score among the prequalified contractors [26]. Hence, to address this problem, in the present work it is proposed to combine the bid price score with prequalification score for final selection of the contractor, which will enable the owners or clients to complete the project optimally in terms of time, cost and quality parameters.

In this connection, the normalized technical score, for each contractor, is determined as the ratio of the technical score (OPV) of each contractor against the total technical score of all contractors as shown in Table 11.

Similarly, the bid price score (B_P) which is used to evaluate the bids is computed as the ratio of the base bid price and the proposed bid price of the candidate contractor [28]. The base bid price is the client's Estimated Cost

Table 7 Average fuzzy scores of contractors

Criterion	Contractor P	Contractor Q	Contractor R	Contractor S
A1	(0.6, 0.7, 0.8, 0.9)	(0.67, 0.77, 0.87, 0.93)	(0.53, 0.63, 0.73, 0.83)	(0.5, 0.6, 0.7, 0.8)
B1	(0.73, 0.83, 0.93, 0.97)	(0.33, 0.43, 0.47, 0.57)	(0.53, 0.63, 0.73, 0.83)	(0.5, 0.6, 0.7, 0.8)
B5	(0.27, 0.37, 0.43, 0.53)	(0.47, 0.57, 0.63, 0.73)	(0.6, 0.7, 0.8, 0.9)	(0.8, 0.9, 1.0, 1.0)
C1	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)
C2	(0.4, 0.5, 0.5, 0.6)	(0.5, 0.6, 0.7, 0.8)	(0.53, 0.63, 0.73, 0.83)	(0.67, 0.77, 0.87, 0.93)
C11	(0.8, 0.9, 1.0, 1.0)	(0.8, 0.9, 1.0, 1.0)	(0.8, 0.9, 1.0, 1.0)	(0.33, 0.43, 0.47, 0.57)
C12	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)
D1	(0.5, 0.6, 0.7, 0.8)	(0.5, 0.6, 0.7, 0.8)	(0.4, 0.5, 0.5, 0.6)	(0.6, 0.7, 0.8, 0.9)
D6	(0.4, 0.5, 0.5, 0.6)	(0.6, 0.7, 0.8, 0.9)	(0.2, 0.3, 0.4, 0.5)	(0.6, 0.7, 0.8, 0.9)
E3	(0.5, 0.6, 0.7, 0.8)	(0.8, 0.9, 1.0, 1.0)	(0.8, 0.9, 1.0, 1.0)	(0.8, 0.9, 1.0, 1.0)
E4	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)
E5	(0.2, 0.3, 0.4, 0.5)	(0.67, 0.83, 0.93, 0.97)	(0.8, 0.9, 1.0, 1.0)	(0.67, 0.77, 0.87, 0.93)
E6	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)
F2	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)	(0.4, 0.5, 0.5, 0.6)
F4	(0.5, 0.6, 0.7, 0.8)	(0.6, 0.7, 0.8, 0.9)	(0.4, 0.5, 0.5, 0.6)	(0.67, 0.77, 0.87, 0.93)

Table 8 Defuzzified values (crisp scores) of contractor assessment

Criterion	Contractor P	Contractor Q	Contractor R	Contractor S
A1	0.75	0.81	0.68	0.65
B1	0.867	0.45	0.6833	0.65
B5	0.4	0.6	0.75	0.925
C1	0.5	0.5	0.5	0.5
C2	0.5	0.65	0.6833	0.8084
C11	0.925	0.925	0.925	0.4499
C12	0.5	0.5	0.5	0.5
D1	0.65	0.65	0.5	0.75
D6	0.5	0.75	0.35	0.75
E3	0.65	0.925	0.925	0.925
E4	0.5	0.5	0.5	0.5
E5	0.35	0.867	0.925	0.8084
E6	0.5	0.5	0.5	0.5
F2	0.5	0.5	0.5	0.5
F4	0.65	0.75	0.5	0.8084

Table 9 Normalized defuzzified values of contractor assessment

Criterion	Contractor P	Contractor Q	Contractor R	Contractor S
A1	0.259	0.28	0.2362	0.2248
B1	0.327	0.17	0.2579	0.2453
B5	0.15	0.224	0.2804	0.3458
C1	0.25	0.25	0.25	0.25
C2	0.189	0.246	0.2587	0.306
C11	0.287	0.287	0.2868	0.1395
C12	0.25	0.25	0.25	0.25
D1	0.255	0.255	0.1961	0.2941
D6	0.213	0.319	0.1489	0.3191
E3	0.19	0.27	0.2701	0.2701
E4	0.25	0.25	0.25	0.25
E5	0.119	0.294	0.3136	0.274
E6	0.25	0.25	0.25	0.25
F2	0.25	0.25	0.25	0.25
F4	0.24	0.277	0.1846	0.2985

Value (ECV) to deliver the project without compromising the quality standards (as per contractor document). Higher bid price score indicates that the contractor's proposed bid price is closer to the base bid price and vice versa.

In the present case study, the base bid price (ECV) is given as INR 360,000,000. The proposed bid prices of contractor of contractors P, Q, R and S are INR 363,223,423, INR 389,243,765, INR 436,798,887 and INR 385,678,459 respectively. The bid scores of the four candidate contractors P, Q, R, and S are found to be 0.9913, 0.9249, 0.8435 and 0.9334 respectively. The normalized bid price score determined is as shown in the Table 11. The Overall Evaluation Score (OES) is calculated by combining the technical/prequalification score obtained in FST approach with bid price score, by giving equal weight to both the scores (Table 11). For example, the Overall Evaluation Score (OES) of Contractor P = 0.2243 + 0.2680 = 0.4923. The rank order of contractors P, Q, R and S is set based on the OES or combined score as **3–2–4–1**.

It can be observed from the final rank order in Table 11 that the ranks 1 and 2 (of contractors S and Q) remained

Table 10 Overall priority values (OPV) of contractors using ALL respondents' RRI

Criteria	Criteria Priority	Contractor Priority Value (CPV)			
	Value (RII)	Contractor P	Contractor Q	Contractor R	Contractor S
A1	0.094	0.259	0.28	0.2362	0.2248
B1	0.1293	0.098	0.106	0.0891	0.0848
B5	0.1188	0.15	0.224	0.2804	0.3458
C1	0.0415	0.25	0.25	0.25	0.25
C2	0.0432	0.095	0.095	0.0946	0.0946
C11	0.0455	0.287	0.287	0.2868	0.1395
C12	0.0417	0.25	0.25	0.25	0.25
D1	0.1122	0.098	0.098	0.098	0.098
D6	0.1177	0.213	0.319	0.1489	0.3191
E3	0.0388	0.19	0.27	0.2701	0.2701
E4	0.0392	0.25	0.25	0.25	0.25
E5	0.0401	0.119	0.294	0.3136	0.274
E6	0.0383	0.25	0.25	0.25	0.25
F2	0.0508	0.25	0.25	0.25	0.25
F4	0.0491	0.24	0.277	0.1846	0.2985
	OPV = Σ RII × CPV	0.185	0.221	0.1977	0.2212
	Rank	4	2	3	1

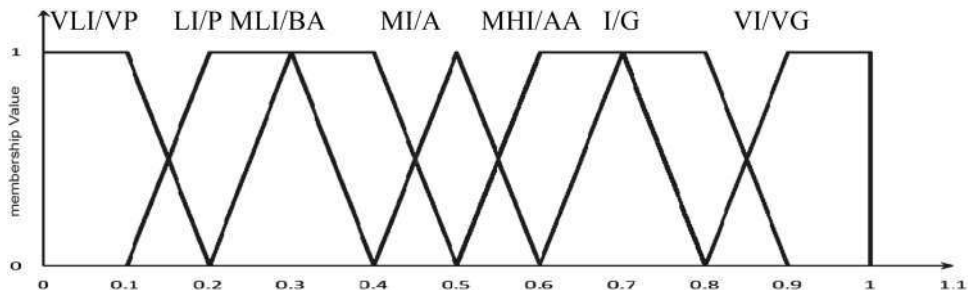

Fig. 1 Linguistic Variables for Rating Criteria and Contractor

Table 11 Final rank order of contractors

Score	Contractor			
	P	Q	R	S
Prequalification/technical score (OPV of contractors in Table 10)	0.185	0.221	0.198	0.221
Normalized technical score	0.224	0.268	0.24	0.268
Bid price score	0.991	0.925	0.844	0.933
Normalized bid price score	0.268	0.25	0.228	0.253
Overall evaluation score (OES)	0.492	0.518	0.468	0.521
Final rank order	3	2	4	1

same as those based on prequalification score while there is a small variation in ranks 3 and 4 between the rankings obtained based on prequalification score and combined scores. But, Contractor-S emerged as the most desired in both cases. Further, it is to be noted that the final rank order is obtained by attributing equal importance or weight to both technical and bid price scores. Hence, FST approach can be considered as a method which could predict the potential contractor more reliably considering the uncertainties in the selection process while the combined score (OES) aids in selecting the optimal contractor. This could be visualized from the change in the final rank order of

contractors as compared to the ranking based on prequalification score alone.

Conclusions

1. The study reveals that Fuzzy Set Theory (FST) provides a reasonable and efficient basis for contractor evaluation to address the uncertainty in rating criteria and contractors.
2. The FST approach offers a reliable basis for decision making as it facilitates an integration of the weights of criteria obtained from industry survey and the evaluations of decision makers. The decisions arrived are relevant as they reflect the polarized views of clients and contractors.
3. FST approach could predict the optimal contractor more reliably considering the combined score of the prequalification and the Bid Price Scores.
4. Quality decisions such as predicting the potential contractor can be made more reliably using FST approach.
5. The proposed methodology of FST is a fool proof method and can be customized to other sectors also.

Appendix: Sample Questionnaire

This questionnaire lists out several evaluation criteria, subcriteria and their measures that are normally considered by the project owners/clients or their representatives to assess the contractors' potential to execute the construction project under consideration. Please give your rating, by ticking appropriate one, based on your experience with contractor selection process, their relevance or level of importance in assessing the contractors' potential to deliver the project at hand.

Scale	Meaning
IR	Particular criterion/attribute (measure) is irrelevant in assessing the contractor's potential
VLI	It has very low importance in assessing the contractor's potential
LI	It has low importance in assessing the contractor's potential
MI	It has medium importance in assessing the contractor's potential
I	It is important in assessing the contractor's potential
VI	It is very important in assessing the contractor's potential

Respondent Details

1. Name of the respondent:_____; Experience:___Years.
2. Respondent Type: Public client / Private client / Contractor or Contracting company.
3. (i) Name & address of department/Firm/Contracting company working for_____
   (ii) Designation of respondent: _____
   (iii) Class of contractor/ Type of company: _____

Place: _____
Date: _____ Signature of Respondent

A	Contracting company's attributes	IR	VLI	LI	MI	I	VI
1.	Age (experience) and registration of the contractor's firm/company						
2.	Familiarity with regulating authorities						
3.	Familiarity with local working culture						
4.	Company's negotiating skill						
5.	Company's trade union record						
6.	Prior business relationship						
7.	Company proximity to project						
8.	Health and safety record of the company						
9.	Achievement of quality level (e.g., ISO: 9000:14000)						
10.	Post-business attitude (e.g., claims and counter-claims)						
11.	Past failures						
12.	Record of firm's social responsibility						

B	Experience record	IR	VLI	LI	MI	I	VI
1.	Experience of working on similar projects						
2.	Experience with owner's organization						
3.	Experience in local area						
4.	Experience in similar geographical and weather conditions						
5.	Type and size of projects completed in past 5 years						
6.	Highest value of project executed in past 5 years						

C	Past performance of the contractor	IR	VLI	LI	MI	I	VI
1.	Work quality in completed projects (i.e., third party quality certification and incentives awarded)						
2.	Adherence to time schedule in past works						
3.	Percentage of past works completed within the agreed contract value						
4.	Percentage of works sublet in past projects						
5.	Standard of sub-contractors' works in past projects						
6.	Attitude towards incomplete/correcting faulty works						
7.	Cordial Relationship with past project clients/owners						
8.	Relationship with sub-contractors						
9.	Relationship with suppliers						
10.	Relationship with regulating authorities						
11.	Blacklisting in past projects						
12.	Quality of service during defect liability period						
13.	No. of arbitral awards or court decisions (litigation history) in past 5 years						

D	Financial capability of the contractor	IR	VLI	LI	MI	I	VI
1.	Current commitments						
2.	Authorized and paid-up capitals						
3.	Working capital						
4.	Current and fixed assets						
5.	Net worth						
6.	Turnover						
7.	Profit generating ability of the company						
8.	Liquidity status of the company						
9.	Capital structure of the company (amount of debt and equity)						
10.	Reference of financial institutions						
11.	Balance sheet data						
12.	Credit rating						
13.	Financial closure (finances-arrangement) for the project						

A	Contracting company's attributes	IR	VLI	LI	MI	I	VI
E	Performance potential of the contractor	IR	VLI	LI	MI	I	VI
1.	Qualification and experience of management staff						
2.	Availability of in-house skilled labour						
3.	Availability of plant and equipment resources						
4.	Present work load (works on hand) and capability to support the current project						
5.	Quality control and assurance program						
6.	Specialized knowledge of particular construction method						
7.	Availability of in-house design capacity						

F	Project specific criteria	IR	VLI	LI	MI	I	VI
1.	Construction method statement						
2.	Specified project time schedule						
3.	Qualification and experience level of the project manager						
4.	Qualification & experience of professional and technical staff						
5.	Experience level of the project team on similar type of project						
6.	Number of direct workers available for the project.						
7.	Availability of testing equipment as quality assurance						
8.	Health and safety setup for the project						
9.	The Contractor's cost and time control considerations						
10.	Reputation of sub-contractors to be used for the project						
11.	Type of performance bond (through bank or surety company)						
12.	Payment schedule						
13.	Risk sharing level of the project owner						

G	Other criteria	IR	VLI	LI	MI	I	VI
1.	Bid or tender price						
2.	Advance payment						
3.	Quoted project duration						
4.	Defect liability period						

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Short communication

Acid resistance of quaternary blended recycled aggregate concrete

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ABSTRACT

The possibility of reusing the aggregate from demolished structures in fresh concrete, in order to reduce the CO_2 impact on the environment [23] and to preserve natural resources, was explored worldwide and it is established that recycled aggregates can be used as a partial replacement of natural aggregates. Due to its potential to be used in eco-friendly structures and shortage of supply of natural aggregates in some parts of the world, there is an increasing interest in using the recycled aggregate. The durability aspects are also of equal concern along with the strength and economy of any material to be used in the construction. Studies reveal that the behaviour of ternary and quaternary blended concretes is superior from durability point of view compared to conventional concrete. Therefore a study is conducted to assess the acid resistance of recycled aggregate based Quaternary Blended Cement Concrete (QBCC) of two grades M40 and M60. Fly ash and silica fume are fixed at 20% and 10% respectively from the previous studies while two percentages of Nano silica (2 and 3%) were used along with the cement to obtain QBCC. Three percentages of recycled aggregates as partial replacement of conventional aggregate (0%, 50% and 75%) were used in this study. Two different acids (HCL and H_2SO_4) with different concentrations (3 and 5%) were used in this study. Acid resistance of QBCC with Recycled Concrete Aggregate (RCA) is assessed in terms of visual appearance, weight loss, and compressive strength loss by destructive and non-destructive tests at regular intervals for a period of 56 days. The test results showed marginal weight loss and strength loss in both M40 and M60 grades of concretes. The Ultrasonic Pulse Velocity (UPV) results show that the quality of QBCC is good even after being subjected to acid exposure.

1. Introduction

The widespread use of concrete for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats, has increased the demand for cement concrete as a construction material. Due to increase in infrastructure developments, the demand for concrete would increase in future. With the continuing expansion of infrastructure and housing construction, especially in the developing countries of Asia, Africa and South America, the rate of consumption of cement and concrete is bound to grow further. It is estimated that the world cement production will increase to around 4.8 billion tons per annum by the year 2030 [1], resulting in proportionate growth in the production of concrete. This consumes the natural resources on one side and increases the demolition waste on the other. Aggregate recycled from demolished concrete is considered to be waste product which can be utilized effectively to overcome the harmful effect of producing natural aggregate like depletion of natural resources, effect on the surrounding

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environment, etc. Quaternary blended cement concrete has high workability and improved properties apart from usage of industrial wastes like fly ash, silica fume, etc. For any material to be used for construction, the durability properties are also important along with the desired strength and mechanical properties. Hence, a study is undertaken to investigate the acid resistance of Quaternary blended cement concrete made with varying proportion of recycled concrete aggregate subjected to hydrochloric acid and sulfuric acid attack. In this study M40 and M60 grades of concrete with different RCA proportions were used.

Alexander and Fourie [2] measured acid resistance of six different sets of concrete materials using hydrochloric acid in a test method developed at the University of Cape Town. They found that Silica fume concrete showed better acid resistance compared to the standard concrete and the meta-kaolin concrete. Tang et al. [3] carried out study on compressive strength and durability of concrete and covered the effect of alkali aggregate reaction, sulphate attack, steel corrosion and freeze-thaw. Medina et al. [4] conducted studies on the chloride penetration and electrical resistivity, as well as the relationship among the durability indicators that predict concrete performance during its service life. The study showed that chloride penetration was slightly deeper in recycled concretes, while no alterations were observed in the relationship among the durability indicators. Faiz and Supit [5] carried out experimental investigations on the compressive strength and durability properties of high volume flyash concretes containing ultrafine class F fly ash (UFFA). They concluded from their investigation that the introduction of ultra fine fly ash improved early age compressive strength and also durability properties. Chousidis et al. [6] investigated the effect of greek flyash as a partial replacement of cement on the durability and mechanical resistance of concrete immersed in sodium chloride solution (NaCl) and concluded that with increase in flyash content chloride concentration increased which in turn increases corrosion of steel.

Dilbas et al. [7] studied the properties of the specimens made of recycled concrete aggregate with silica fume and without silica fume. The study resulted that the compressive strength of the recycled concrete aggregate was low when compared to the specimens with silica fume mixed in the concrete. Prasad Rao and Kumar [8] concluded that with the increase in the percentage of nano silica the various strength characteristics of the concrete were increased upto 1.5% and with further increase in nano silica the strength decreased. The split tensile strength also indicated the similar trend. Based on the study the strength properties of concrete can be improved by addition of 1.5% of nano silica and 10% of micro silica by weight of concrete. Prasad Rao and Kumar [9] found the optimum values of nano-silica and flyash as 3% and 20% respectively from strength point of view. Abdul Wahab et al. [10] concluded from their study that in triple blended mixes, there is a gradual increase in strength upto 2% of nano silica with 10% condensed silica fume (CSF) in the mix and above there is gradual decrease in the strengths. Finally the study concluded that adequate plasticizers are to be added when nano silica and CSF are used along with the cement in high strength concrete mixes. Seshasayi et al. [11] Carried out an experimental investigation to assess the performance of three types of concrete: the study concluded that Concrete with high volume fly ash showed better resistance when exposed to acidic environment, though strength decreased marginally. Concrete with blended cement is found to be more impermeable than concrete with fly ash mixed at site. Mukesh et al. [12] investigated the mechanical properties and durability performance of concrete produced with Portland silica fume (PSF) and RCA. In this study a gradual reduction in strength with an increase in RCA content was observed. Reducing the w/c of concrete treated with the RCA has led to an enhanced compressive strength, higher resistance to carbonation, and chloride ion ingress. Torben and Erik [13] concluded from their experimental investigations that Recycled aggregate concretes have 15–30% lower modulus of elasticity and 40–60% higher shrinkage than corresponding conventional concretes.

Buttler and Machado [14] carried out an experimental study to evaluate the physical properties of the recycled concrete coarse aggregates and the physical and mechanical properties of the concretes produced with these aggregates. Results indicate that the residues of concrete that were recycled right after generation exhibit higher compressive and tensile strengths when compared to those concretes with natural aggregates because of the presence of a large amount of non-hydrated cement particles. Meinhold et al. [15] demonstrated through their experimental work that the industrial production of a high-grade, durable concrete is possible. Yamato et al. [16] concluded that decrease in strength can be suppressed low by partial use of recycled coarse aggregate. The drying shrinkage of recycled aggregate concrete showed larger value than conventional crushed aggregate concrete whereas shrinkage reducing agent can reduce the drying shrinkage of recycled aggregate concrete. Torben and Soren [24] reported experimental results that show that addition of a plasticizing, an air entraining, a retarding, and an accelerating admixture to original concretes had little or no effect on the properties of new concretes produced from recycled aggregates obtained by the crushing of original concretes. Adam et al. [17] investigated the workability, compressive strength, and elastic modulus of normal-strength concrete with recycled concrete aggregate (RCA) as replacement for coarse natural aggregate (for example, crushed stone, gravel). The results suggest that the RCA water absorption and deleterious material content can be used to prequalify the material for selected concrete strength and stiffness performance objectives. Corinaldesi and Moriconi [18] carried out an investigation by completely replacing natural aggregates with recycled aggregates from a crushing plant in which rubble from building demolition was ground. The results obtained show that because of mineral addition and W/C reduction, recycled aggregates can be used instead of natural aggregates since concretes with similar compressive strength can be obtained. The use of the recycled aggregates with fly ash replacements also has significant cost and environmental advantages over ordinary concrete.

Therefore, in this study, acid resistance of quaternary blended recycled aggregate concrete is studied for two different grades of concrete M40 and M60. The weight loss and strength loss are the main parameters of study. Two acids HCL and H_2SO_4 are used with two different percentages selected, based on the literature available, corresponding to exposure conditions. The loss of strength increased with increased recycled aggregate concrete. However, the value of strength loss is observed to be less compared to earlier researchers' findings [19] due to the addition of powders (Quaternary blending). The results of the investigation are useful for application of QBCC in sewage pipes.

Table 1
Chemical composition of Cement (as per Manufacturers test report).

S. No.	Chemical Property	Limits as per IS	Results
1	Lime Saturation Factor (%)	0.66–1.02	0.82
2	Alumina Iron Ratio (%)	Min 0.665	1.2
3	Insoluble Residue (%)	Max 2%	0.95
4	Magnesia (%)	Max 6%	2.4
5	Sulphuric Anhydride (%)	2.5%–35	1.1
6	Loss on Ignition (%)	Max 5%	2.2

2. Experimental investigation

2.1. Materials, mix proportions and specimen preparation

The raw materials used for this research were OPC 53grade, recycled coarse aggregate, fine aggregate of zone III, fly ash of class F with less than 8% CaO, silica fume, nano silica and super plasticizer CONPLAST SP-430 (Sulfonated Naphthalene based). OPC grade 53 with specific gravity 2.99 is used in this investigation and the chemical composition of cement is shown in Table 1. The physical properties of fly ash, silica fume and nano silica are shown in Table 2. The chemical composition of cement, fly ash and silica fume are given in Tables 3–5 respectively. The recycled coarse aggregate was obtained from 20 year old residential slab that was crushed, cleaned from excess mortar and sieved. The physical properties of Fine and Coarse aggregates are shown in Table 6. The grain size distribution curves are shown in Fig. 1. Hydrochloric acid and sulphuric acid were used for testing acid resistance of QBCC. Twelve groups of mixtures were prepared in the lab with different proportions for M40 and M60 grades of concrete, with six mixes for each. The details of mixes are shown in Table 7.

For the mechanical tests, specimens of 100 mm × 100 mm × 100 mm were prepared. The mixture was filled in the moulds and vibrated. The specimens were demoulded after 24 h and cured under water for 28 days. After curing specimens were immersed in 3% and 5% sulphuric acid and hydrochloric acid solutions separately for a total period of 56 days.

2.2. Methodology

The effect of fly ash and recycled coarse aggregate on the durability of concrete was evaluated by various physical and mechanical tests.

2.2.1. Test for compressive strength

The bearing surface of testing machine and cube specimen were cleaned before placing the specimen in the testing machine. The cube specimen was placed in the machine and the compressive strength of the specimen was calculated by dividing the maximum load applied by cross sectional area of the specimen. The change in compressive strength after acidic exposure was determined by testing the compressive strength of the specimens after selected periods of exposure.

2.2.2. Change in mass

The specimens were removed from acid solution and wiped clean prior to the measurement of mass. Change in mass of specimens was calculated up to 56 days after being subjected to various periods of exposures, i.e., 1, 7, 15, 28 and 56 days. Mass measurements were done using an electronic weighing machine. The specimens were returned to the acidic solution container, immediately after the measurement was done.

2.2.3. Non-destructive test (NDT)

The ultra-sonic pulse velocity (UPV) method is used for non-destructive testing. The main objective of the ultra-sonic pulse velocity method is to establish the homogeneity of the Concrete, the presence of cracks, voids and other imperfections due to changes in the structure of the concrete caused by the exposure condition. For this test, specimens were wiped clean and dried prior to the NDT test. An initial load of 10% of the compressive strength was applied on the concrete specimens, grease was applied on the plain surfaces and then NDT was carried out. The schematic diagram of UPV test is shown in Fig. 2.

Table 2
Physical properties of Fly ash, Silica fume and Nano silica.

Physical property	Results obtained		
	Fly Ash	Silica Fume	Nano Silica
Specific gravity	2.28	2.22	1.31
Bulk density kg/m^3	944	720	–
Average particle size	6.92 μm	< 1 μm	5–10 nm

Table 3
Chemical composition of cement (as per manufacturers test report).

S. No	Chemical Property	Limits as per IS	Results
1	Lime Saturation Factor (%)	0.66–1.02 max	0.82
2	Alumina Iron Ratio (%)	Min 0.665	1.2
3	Insoluble Residue (%)	Max 2%	0.95
4	Magnesia (%)	Max 6%	2.4
5	Sulphuric Anhydride (%)	2.5%–35	1.1
6	Loss on Ignition (%)	Max 5%	2.2

Table 4
Chemical composition of fly ash.

S. No.	Chemical Property	Result (% mass)
1	Loss on Ignition	0.43
2	Alumina (as Al_2O_3)	16.31
3	Silica (as Sio_2)	60.82
4	Iron (as Fe_2O_3)	17.17
5	Calcium (as CaO)	4.64
6	Magnesium(MgO)	Not found
7	Sodiun (as Na_2O)	0.34
8	Potassium (as K_2O)	0.08

Table 5
Composition of Silica fume as per manufacturer test certificate.

S. No	Chemical requirements	Specification as per IS	Test results
1	Silicon dioxide, Sio_2	Minimum 85%	85.42%
2	Moisture content	Maximum 3%	0.62%
3	Loss of Ignition	Maximum 6%	2.26%
4	Physical requirement (> 45 μm)	Maximum 10%	0.8%
5	Pozzolona activity index	Minimum 10.5%	13.8%
6	Specific surface (m^2/gm)	Minimum 15	19
7	Bulk density (kg/cu m)	500–700	610

Table 6
physical properties of Fine and Coarse Aggregate.

Physical property tested	Results obtained		
	Fine Aggregate	Coarse Aggregate	Recycled Coarse Aggregate
Specific Gravity	2.52	2.835	2.72
Fineness Modulus	3	7.313	7.309
Water Absorption	–	0.53	2.68

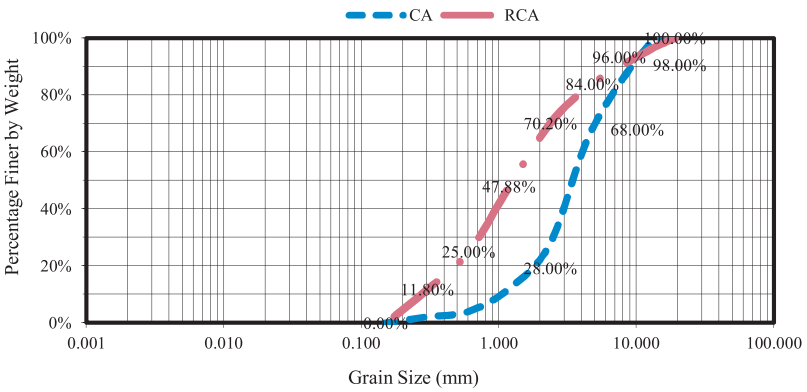


Fig. 1. Grain size distribution of Coarse Aggregate.

Table 7
Mix proportions of twelve groups of mixtures.

Grade	Mix	Cement content (%)	fly ash content (%)	silica fume content (%)	nano silica content (%)	RCA (%)	Mix Proportion[a]
M40	M1	68	20	10	2	0	Powder:FA: CA = **1:1.36:2.22 with W/**
	M2	67	20	10	3	0	**P = 0.36**
	M3	68	20	10	2	50	
	M4	67	20	10	3	50	
	M5	68	20	10	2	75	
	M6	67	20	10	3	75	
M60	M7	68	20	10	2	0	Powder:FA: CA = **1:1.07:1.85 with W/**
	M8	67	20	10	3	0	**P = 0.30**
	M9	68	20	10	2	50	
	M10	67	20	10	3	50	
	M11	68	20	10	2	75	
	M12	67	20	10	3	75	

[a] Note: The mix proportions are taken by weight.

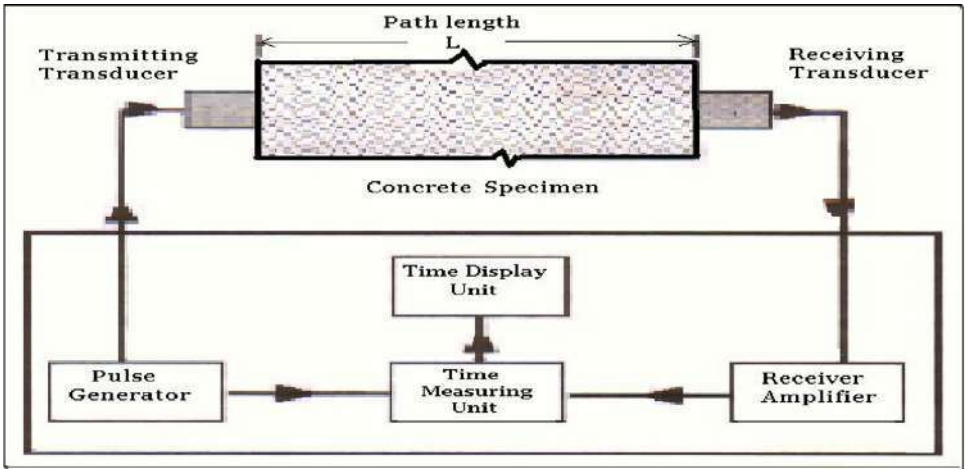


Fig. 2. Schematic Diagram of Ultrasonic Pulse Velocity Test.

3. Results and discussions

3.1. Workability of concrete

The super-plasticizer dosage is adjusted in all the mixes to achieve the required workability. The slump value for all the mixes ranged between 50 and 80 mm. The workability of concrete reduced as the recycled aggregate content increased while the increase in nano-silica improved workability.

3.2. Compressive strength

The compressive strengths of the mixes after 28 days of curing and the standard deviations are shown in Table 8.

For M40 grade of concrete the target mean compressive strength could be obtained for both the mix proportions varying percentage of nano silica with 0% and 50% of recycled coarse aggregate while for M60 grade of concrete target mean strength could only

Table 8
Compressive strengths after 28 days of curing.

Grade of Concrete	Compressive Strength (N/mm^2)			Standard Deviation		
	0% RCA	50% RCA	75% RCA	0% RCA	50% RCA	75% RCA
M40 (2% NANO SILICA)	56.44	52	41.73	1.229	1.980	2.28
M40 (3% NANO SILICA)	55.46	49	40.12	1.282	1.536	2.177
M60 (2% NANO SILICA)	68.60	55	47.20	1.058	2.182	3.732
M60 (3% NANO SILICA)	61	52	44.60	1.621 1.621	1.916	3.306

Table 9
Loss percentage of compressive strengths of M40 grade with 2% nano silica.

Grade	Acid	Compressive Strength N/mm^2					
		0% RCA	Loss (%)	50% RCA	Loss (%)	75% RCA	Loss (%)
M40	3% HCL	51.50	8.76	47.40	8.85	37.99	8.96
	5% HCL	51.35	9.02	47.27	9.10	37.88	9.22
	3% H_2SO_5	50.40	10.70	46.39	10.78	37.19	10.88
	5% H_2SO_4	49.89	11.60	45.92	11.70	36.78	11.86

be attained for the mix with 2% nano silica and 0% recycled aggregate (Table 8). For M60 grade concrete with 3% nano silica, the design strength could be achieved with 0% RCA though the target strength could not be achieved (Table 8). The percentage loss in weights and compressive strengths of the specimens exposed to acidic solutions for various periods are compared to that of the control specimens not exposed to the acids.

3.3. Loss in compressive strength

The percentage loss of compressive strength for M40 grade concrete with 2% and 3% nano silica and 0%, 50% and 75% of RCA, due to acid effect are as shown in Tables 9 and 10 while the same for M60 grade of concrete are shown in Tables 11 and 12. The loss of compressive strength ranged from 8.7 to 11.9% in M40 grade concrete when exposed to HCL or H_2SO_4. A marginal increase in percentage strength loss is observed as the nano silica content or percentage of RCA increased in the mix. The percentage loss in compressive strength is observed to be more in the specimens exposed to H_2SO_4 compared to those exposed to HCL. The compressive strength is found to reduce as the percentage RCA content increased in the mix (by 50% or more) and the loss of compressive strength due to acid exposure also increased as the percentage of RCA increased leading to further reduction in the strength of RAC. Similar trend is observed in M60 grade concrete also with the percentage change in compressive strength varying from 8.8 to 12.

3.4. Change in weight

The results of percentage change in weight of the specimens for M40 concrete with 2% and 3% nano silica and 0%, 50% and 75% of RCA due to different concentrations of acid effect are shown in Figs. 3 and 4 and the same for M60 concrete are shown in Figs. 5 and 6.

The weight loss on the first day of immersion is negative due to absorption of acid solution by the specimens, but there is gradual increase of loss in weights seen on 7th day, 15th day, 28th day and 56th day of immersion. The weight loss observed is marginal due to the acid exposure in both the acids HCL and H_2SO_4. However, the weight loss due to the exposure of concrete of both the grades M40 and M60 is more in case of H2SO4 compared to HCL. The percentage loss of weight ranged between 1.5–2.9 in case of HCL and 1.65–3.5 in case of H_2SO_4. The weight loss is also found to increase with the increasing percentage of RCA in both the grades of concretes tested. There is no effect of nano silica on the weight loss in both the grades of concrete and similar trend in weight loss is observed for 2% and 3% nano silica.

3.5. Ultrasonic pulse velocity values

The results of all the specimens tested for ultrasonic pulse velocity show that the concretes of both the grades M40 and M60 are performing well even after 56 days of exposure to acids with the UPV values ranging between 3.5–4.5 km/s. However, there is a reduction in UPV values with the concentration of acid, increasing age of exposure and increasing RCA content indicating decreasing quality. The specimens with 3% nano silica performed well compared to the specimens with 2% nano silica in both HCL and H2SO4 for both the grades of concrete with recycled aggregate (Figs. 7–10).

The UPV values of specimens with 3% nano silica show that there is no change or a slight increase in these values with age in both M40 and M60 grades of concrete without recycled aggregate indicating good acid resistance (Figs. 7(b), 8(b), 9(b) and 10(b)). Similar trend is observed in M60 grade concrete with 2% nano silica (Figs. 9(a) & 10(a)). However, in M40 grade concrete with natural

Table 10
Loss percentage of compressive strengths of M40 grade with 3% nano silica.

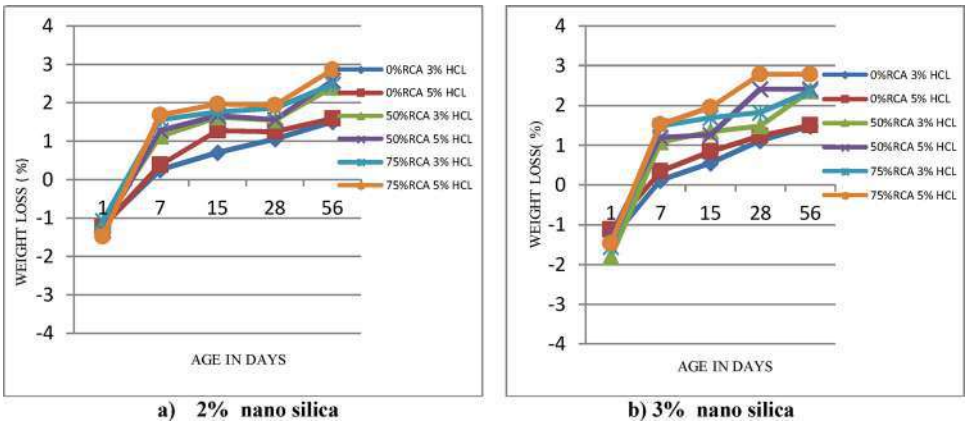
Grade	Acid	Compressive Strength N/mm^2					
		0% RCA	Loss (%)	50% RCA	Loss (%)	75% RCA	Loss (%)
M40	3% HCL	50.53	8.89	44.64	8.90	36.51	9.10
	5% HCL	50.41	9.10	44.50	9.18	36.32	9.46
	3% H_2SO_4	49.49	10.76	43.68	10.86	35.68	11.06
	5% H_2SO_4	48.98	11.68	43.23	11.78	35.31	11.89

Table 11
Loss percentage of compressive strengths of M60 grade with 2% nano silica.

Grade	Acid	Compressive Strength N/mm^2					
		0% RCA	Loss (%)	50% RCA	Loss (%)	75% RCA	Loss (%)
M60	3% HCL	62.56	8.80	50.12	8.88	42.96	8.89
	5%HCL	62.31	9.16	49.91	9.25	42.66	9.62
	3% H_2SO_4	61.18	10.82	49.01	10.90	41.97	11.08
	5% H_2SO_4	60.6	11.66	48.55	11.72	41.57	11.92

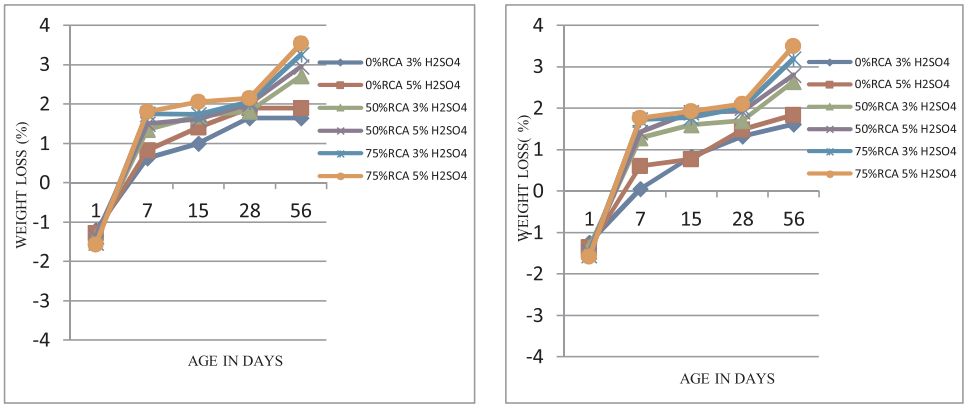
Table 12
Loss percentage of compressive Strengths of M60 grade with 3% nano silica.

Grade	Acid	Compressive Strength N/mm^2					
		0% RCA	Loss (%)	50% RCA	Loss (%)	75% RCA	Loss (%)
M60	3% HCL	55.56	8.92	47.34	8.96	40.53	9.12
	5% HCL	55.39	9.19	47.04	9.53	40.16	9.95
	3% H_2SO_4	54.35	10.90	46.29	10.98	39.60	11.21
	5% H_2SO_4	53.85	11.72	45.82	11.88	39.25	12



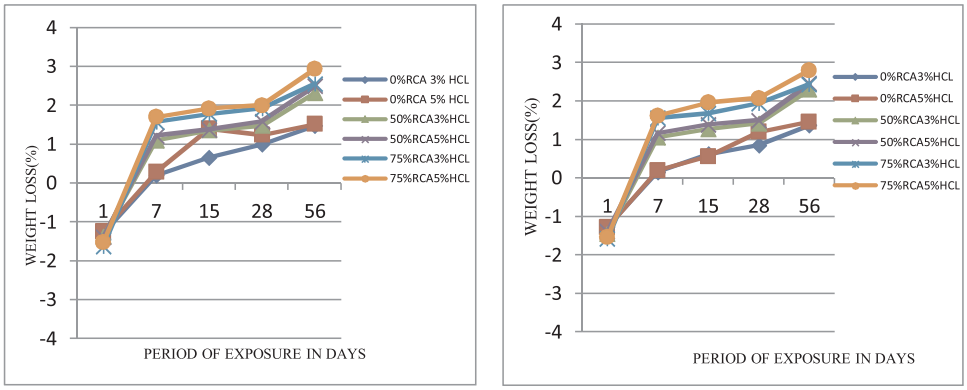
a) 2% nano silica b) 3% nano silica

Fig. 3. Percentage weight loss vs period of exposure for M40 Concrete with varying RCA exposed to 3% and 5% HCL.



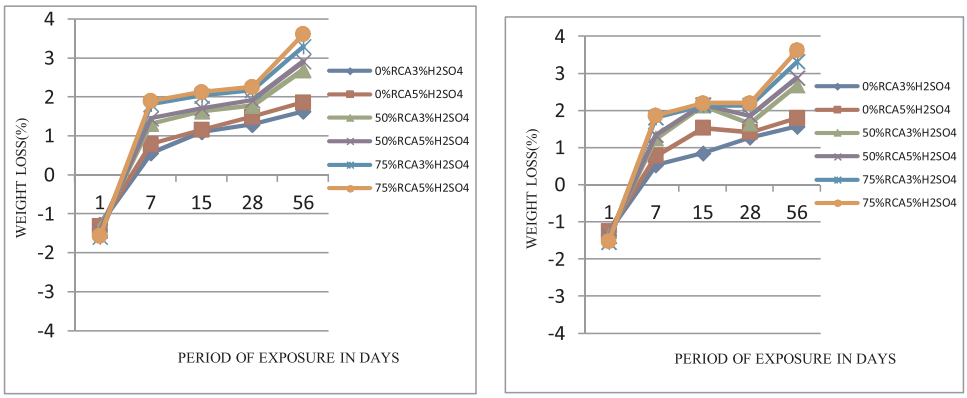
a) 2% nano silica b) 3% nano silica

Fig. 4. Percentage weight loss vs period of exposure for M40 Concrete with varying RCA exposed to 3% and 5% H_2SO_4.



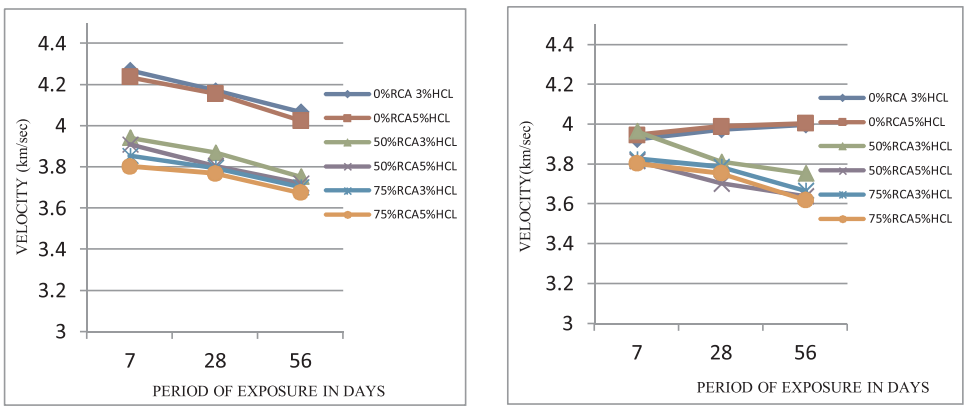
a) 2% nano silica b) 3% nano silica

Fig. 5. Percentage weight loss vs period of exposure for M60 Concrete with varying RCA exposed to 3% and 5% HCL.



a) 2% nano silica b) 3% nano silica

Fig. 6. Percentage weight loss vs period of exposure for M60 Concrete with varying RCA exposed to 3% and 5% H_2SO_4.



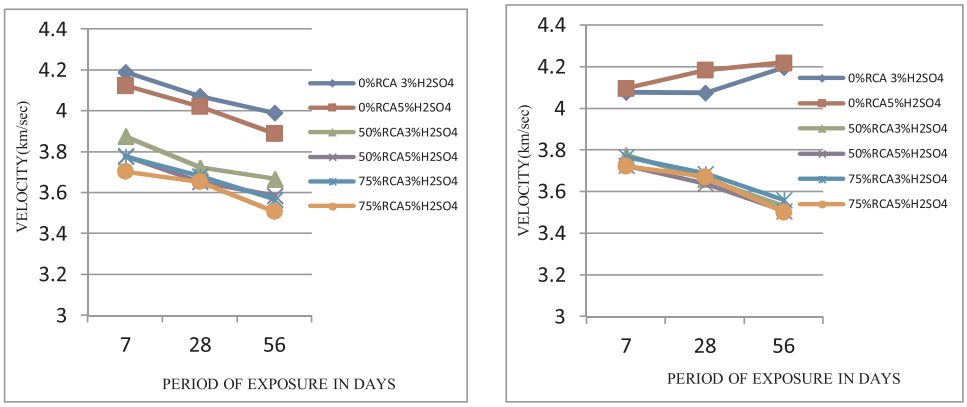
a) 2% nano silica b) 3% nano silica

Fig. 7. Variation of UPV with period of exposure for M40 Concrete with varying RCA exposed to 3% and 5% HCL.

aggregates and with 2% nano silica, there is a reduction in UPV values with age (Figs. 7(a) and 8(a)).

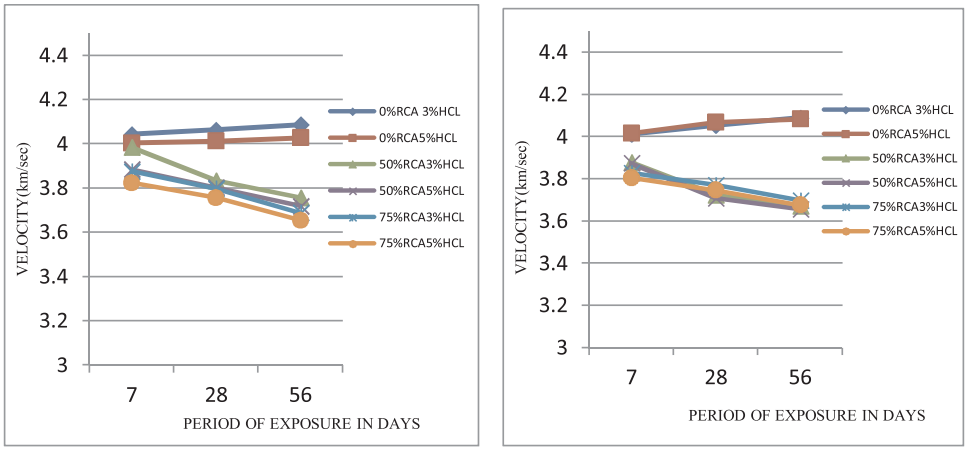
3.6. Comparison of results with earlier work

Hiren Patel et al. [20] conducted tests on acid resistance of M30 Grade concrete and reported weight loss of 1.5% when exposed to



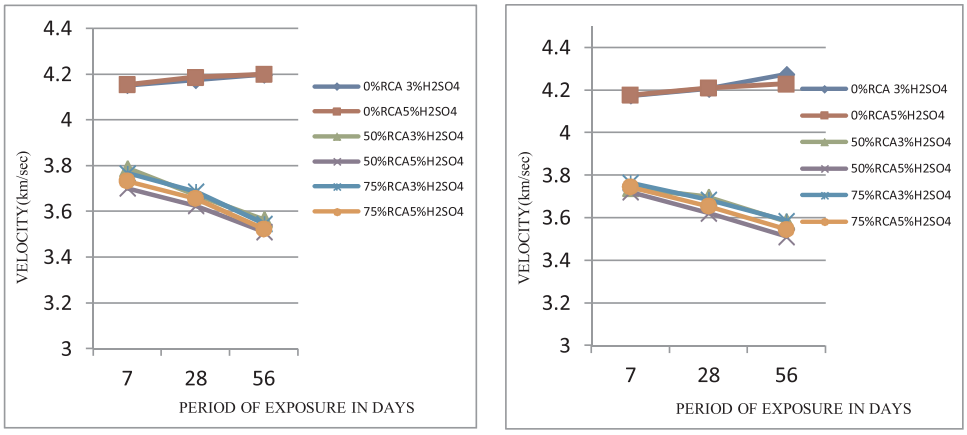
a) 2% nano silica b) 3% nano silica

Fig. 8. Variation of UPV with period of exposure for M40 Concrete with varying RCA exposed to 3% and 5% H_2SO_4.



a) 2% nano silica b) 3% nano silica

Fig. 9. Variation of UPV with period of exposure for M60 Concrete with varying RCA exposed to 3% and 5% HCL.



a) 2% nano silica b) 3% nano silica

Fig. 10. Variation of UPV with period of exposure for M60 Concrete with varying RCA exposed to 3% and 5% H_2SO_4.

5% H2SO4 for 28 days and this value is close to our experimental values for M40 Grade which is around 2%. Mohammed Fouad Alnahhal et al. [19] observed a strength loss of up to 63% in NAC and 67% in RAC when exposed to 3% HCl solution and these losses were reduced to 39% by adding 30% of rice husk ash. These values are on higher side compared to our observations in the experimental investigation which is around 9%. This may be due to the presence of mineral admixtures like fly ash, silica fume and nano silica. Sanjukta Sahoo et al. [21] reported a strength loss of 8% when exposed 1% H2SO4 and this value is comparable to our experimental value which is 9% when exposed to 3% H_2SO_4.

4. Conclusions

- The target strength is attained in quaternary blended cement concrete of grade M40 upto 50% of recycled aggregate as partial replacement of natural aggregate but concrete with 75% of recycled coarse aggregate could not attain target strength.
- The target strength could not be attained in quaternary blended cement concrete of M60 grade when recycled aggregate is used 50% or more as partial replacement of natural aggregate.
- The weight loss of the specimens increased with the increase in the percentage of recycled coarse aggregate in the mix. The loss in the weight was more in the specimens with 3% nano silica when compared to specimens with 2% nano silica.
- The loss due to acid exposure is more in H_2SO_4 compared to HCL in both the grades of concrete tested, the maximum loss of compressive strength being 12% for QBCC with 75% RCA and 3% nano silica. However, the ultra-sonic pulse velocity ranged between 3.5 km/s–4.5 km/s for both M40 and M60 grade QBCC after 56 days of acid exposure, indicating good quality condition.
- Quaternary blended cement concrete with 0% and 50% RCA are more resistant to acid attack when compared to 75% RCA as partial replacement of natural aggregates.

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Update

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Erratum regarding missing Declaration of Competing Interest statements in previously published articles

Declaration of Competing Interest statements were not included in published version of the articles that appeared in previous volumes of Case Studies in Construction Materials. Hence, the authors of the below articles were contacted after publication to request a Declaration of Interest statement:

1. Effects of calcined halloysite nano-clay on the mechanical properties and microstructure of low-clinker cement mortar2018S2214-5095(18)30278-X10.1016/j.cscm.2018.e0021310C
2. Applicability of GPR and a rebar detector to obtain rebar information of existing concrete structures2019S2214-5095(18)30406-610.1016/j.cscm.2019.e0024011C
3. Effect of aging process on the microstructure, corrosion resistance and mechanical properties of stainless steel AISI 2042019S2214-5095(19)30044-010.1016/j.cscm.2019.e0025311C
4. High performance fibre reinforced cementitious composites: Six memos for the XXI century societal and economical challenges of civil engineering2019S2214-5095(18)30372-310.1016/j.cscm.2019.e0021910C
5. The architrave a tasselli2019S2214-5095(19)30073-710.1016/j.cscm.2019.e0025211C
6. Long term performance of gravel base course layers in asphalt pavements2018S2214-5095(18)30187-610.1016/j.cscm.2018.e002089C
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11. Studies of the effect of recycled aggregates on flexural, shear, and bond splitting beam structural behavior2018S2214-5095(18)30181-510.1016/j.cscm.2018.e001869C
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18. A critical review on application of alkali activated slag as a sustainable composite binder2019S2214-5095(19)30209-810.1016/j.cscm.2019.e0026811C
19. The probability distribution of pitting for accelerated corrosion reinforcement2018S2214-5095(18)30150-510.1016/j.cscm.2018.e001939C

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20. Alkali-silica reaction in Southern-Finlandâ^{TM}s bridges2018S2214-5095(18)30026-310.1016/j.cscm.2018.03.0068C
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A STUDY ON PROPERTIES OF HIGH STRENGTH RECYCLED AGGREGATE CONCRETE WITH SYNTHETIC FIBRES

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Abstract Recycled concrete aggregates (RCA) are crushed, graded inorganic particles processed from the materials of concrete demolition debris. The aim of this research work is to study the behavior, in fresh and hardened states, of high strength structural concrete with recycled aggregates and synthetic fibres. The scope of this paper is to compare fresh and hardened state properties of high strength concrete by using various proportions of recycled coarse aggregates (0, 50% and 100% replacement of natural aggregates) along with PP fibres (0, 0.2, 0.3 and 0.4% by volume of concrete). The parameters of investigation include tests on workability, compressive, flexural and indirect tensile strengths, and modulus of elasticity. It is observed that the workability of concrete considerably reduced with the increasing quantities of recycled aggregate and polypropylene fibres. The results showed a gradual decrease in compressive strength, tensile strength and secant modulus of elasticity as the percentage of recycled aggregate used in the concrete mix increased.
Keywords: High Strength Concrete, Recycled Concrete Aggregate, Polypropylene Fibres, Mechanical Properties.

1. INTRODUCTION

Providing shelter to its subjects is the fundamental duty of all governments which requires several materials such as concrete, steel, brick, stone and so on. However, the cement concrete remains the main construction material and for its suitability and adaptability concerning the changing environment. This widely used material must also be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy and major emphasis must be laid on the use of wastes and byproducts in cement and concrete. The utilization of recycled aggregate is particularly very promising as 75 percent of concrete is made of aggregates. In that case, the enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in densely populated urban areas. This can easily be done by recycling the aggregate. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost-effectiveness.

The extensive research on Recycled Concrete Aggregate (RCA) has started from the year 1945 in various parts of the world after World War II but in a fragmented manner. The first effort has been made by Nixon (1978)[1] who compiled all the works on recycled aggregate carried out between 1945-1977 and prepared a state-of-the-art report while concluding that some researchers have examined the basic properties of concrete in which the aggregate is the product of crushing another concrete. A comprehensive state-of-the-art document on the recycled aggregate concrete has been presented by Hansen et al. (1986)[2] in which detailed analysis of data has been made, leading towards the preparation of guidelines for production and utilisation of RCA. RILEM technical committee 121-DRC[3] has given broad guidelines for the utilisation of RCA. Several researchers concluded [4, 5] that RCA can be used for normal strength concrete. Limbachiya et al.(2000)[6] concluded that RCA could also be utilised in high strength concrete and proper mix proportioning is the key to achieve strong and durable concrete. Though concrete lends itself to a variety of innovative designs, it suffers from several drawbacks that affect quality constructions such as Lack of toughness and ductility, Flexural strength limitation, Low abrasion/wear resistance, Inherent microcracks and Limited impact resistance.

To overcome above defects addition of Fibre to concrete is one of the solutions. Correct quantities and the right size of fibres when incorporated into conventional concrete substantially add to the strength when compared with concrete products made without fibre. FRC is also tougher and more resistant to impact in comparison with plain concrete. FRC conventionally uses steel fibre, and a lot of research work is being carried out on synthetic fibres also such as polyester, polypropylene. Synthetic fibre reinforced concrete (SNFRC) makes use of man-made fibres that are derived from organic polymers like acrylic, aramid, carbon, nylon, polyester, polythene and polypropylene fibres which have been tried as reinforcing material in Portland cement concrete. Since the use of PPFRC reduces water penetration and permeability by more than 50% with respect to control concrete, IS 2645 recommends it as waterproofing admixture. However, the basic attributes of PPFRC are a reduction in shrinkage cracks and improvement in elastic properties of concrete.

Dave and Desai(2007)[7] found the addition of fibres produce non linear curve after first crack and reaches its peak at the ultimate strength of maximum sustainable static load and also the intricate matrix formed by huge number of fibres increase the compressive strength of a desired mix of concrete. Polymeric fibres having relatively low modulus of elasticity which

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reduce the initial stiffness and ultimate strength but their better extensibility results in an appreciable post-peak performance and toughness. Tam and Tam (2008)[8] developed a two-stage mixing approach to improve the quality of recycled coarse aggregate concrete for high-grade applications. The effects for the two-stage mixing approach can be attributed to the porous nature of recycled aggregate, and hence pores and cracks can be successfully filled up during the pre-mixing process, yielding denser concrete, improved interfacial zones around recycled aggregate and thus a higher strength in comparison with concrete using traditional mixing approaches.

Mukai et al. (1988)[9] investigated the failure in low reinforced concrete beam specimens made with RCA and conventional aggregate concrete. The study also included the shear strength of low reinforced concrete of both the beams. The authors observed first cracking in RCA beam specimen. However, the ultimate load was similar in both the beams. Etxeberria et al. (2007)[10] produced four different recycled aggregates concretes made with 0%, 25%, 50% and 100% of recycled coarse aggregates, respectively. The authors concluded the utilization of RCA produced lower modulus of elasticity compared to conventional concretes and verified the numeral models proposed by several researchers. Tavakoli and Soroushian (1996)[11] carried out experimental work to determine the compressive, split tensile and flexure strength of recycled aggregate concrete and compared them with those of concrete made with the crushed natural aggregate. The authors concluded that the strength characteristics of recycled aggregate concrete are influenced by the strength of the original concrete, the ratio of coarse to fine aggregate in the original concrete, the ratio of the top size of aggregate in the original concrete to that of the recycled aggregate and the water absorption of recycled aggregate. Ajdukiewicz and Kliszcewicz (2002)[12] considered different grades of concrete ranging from M40 to M70 in their study and the recycled aggregate used was obtained from crushing concrete having a strength ranging from M40-M60.The results showed that the properties of original concrete significantly influence mechanical properties of recycled aggregate and it is possible to obtain recycled aggregate with higher strength than the original one. K.J.Rao(2011)[13] conducted tests on concrete using glass/polyester fibres and Recycled aggregate and concluded that plain concrete beams with 0% RCA and 50% RCA failed once the first crack was initiated, but the large deflections of fibrous concrete beams before failure indicated improved ductility.

In the present paper, an effort is made to compare some of the mechanical properties of high strength Recycled Aggregate Concrete (RAC) with the Natural Aggregate Concrete (NAC) using different percentages of PP 3S polypropylene fibres.

2. MATERIALS USED AND EXPERIMENTAL METHODOLOGY

Commercially available OPC 53 grade cement conforming to IS:12269[14] was used for preparing cement paste and concrete. The standard tests were conducted to find the characteristics of cement, and the results are tabulated in Table 1. Potable water available in the laboratory was used for the mixes.

Table1: Chemical composition and Physical properties of Cement

Chemical composition	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	SO_3	LOI
Value (%)	63.4	20.1	4.1	3.3	3.6	0.2	0.4	2.1	2.4

Physical properties	Blain fineness (m^2/kg)	Average primary particle size	Specific gravity
Value	308	28.2	3.14

Fine Aggregate The local river sand passing through 4.75 I.S.Seive and retained on 150 micron was used for preparing the concrete. The sand is free from clayey matter, salt and organic impurities. The sand is tested for various properties like specific gravity, bulk density, etc., as per Grain size distribution of sand shows that it is close to the zone-III of IS:383[15]

Natural coarse aggregate Crushed granite stone aggregate of nominal size passing 20mm was used throughout the work.

Recycled concrete aggregate Field demolished concrete is used in the present study to produce the recycled aggregates. The concrete debris was collected with the age 7 to 10 years structure and broken into pieces of approximately 80 mm size with the help of hammer & drilling machine. The foreign matters were sorted out from the pieces. Further, those pieces were crushed in a laboratory jaw crusher and sieved through a sieve of 4.75 mm to remove the finer particles.

Super plasticizer Polycarboxylic Ether based supplied by M/s FOSROC Chemicals India Private Limited was used.

Water Fresh potable water free from organic matter and oil was used for mixing of the concrete.

PP 3S Polypropylene Construction Fibres are triangular polyester fibre in cross section with cut length of 6mm & 12mm which is being widely used in Indian construction industry. It is much cheaper than any other imported construction fibres. At the specified dosage of 0.25% by weight of cement, there are a million of fibres which form a mesh in concrete. The spacing is approximately less than 1mm between any two fibre filaments in any coordinate of the matrix.

3. EXPERIMENTAL INVESTIGATION

The workability test includes slump and compaction factor and the hardened state properties like compressive, flexural and split tensile strengths, and static modulus of elasticity were conducted on standard test specimens in this investigation.

Design Mix-ACI method of mix design was adopted and the grade of concrete is M60. The various ingredients and their quantities are shown in Table 2.

Table 2.Quantities of various ingredients of M-60 grade concrete

Cement (kg/m^3)	594
Sand (kg/m^3)	596.75
Aggregate(kg/m^3)	1080
Water(ltrs)	185
Super plasticizer(kg/m^3)	5.5
28Days Cube compressive strength (MPa)	68.75

4. TEST RESULTS AND DISCUSSIONS

Results obtained from the experimental investigation are the mechanical properties of M-60 grade concrete with 0, 50 and 100% RCA containing PP fibres. They are compared with the mechanical properties of plain concrete. The test results are shown graphically in the Figures 1 to 8.

4.1 Workability of concrete

The slump test values of concrete grade M-60 with 0, 50 and 100% RCA with different percentages of Recron 3S PP fibres viz, 0, 0.2, 0.3 and 0.4% by weight of cement are shown in Fig 1. For normal aggregate the slump and compaction factor is satisfactory. From the results obtained, it is observed that there is no appreciable change in workability of conventional concrete and concrete with RCA and PP fibres. However, there is a marginal decrease in the workability as fibres were introduced.

4.2 Compressive Strength

Cube specimens were tested for compression, and the ultimate compressive strength was determined from failure load measured using the compression testing machine. The average values of the compressive strength of 3 specimens for each category at the ages of 7 and 28 days are shown in Fig 2. There is a marginal increase in compressive strength as the fibre content increased from 0 to 0.2% in natural aggregate concrete and there is a drop in the strength on further increase in fibre content. The same trend is observed even in recycled aggregate concrete upto a replacement of 50% though there is a marginal decrease in strength of recycled aggregate concrete compared to natural aggregate concrete. However, there is a continuous reduction in strength when the natural aggregate is totally replaced by recycled aggregate for all percentages of fibres. The behavior is observed to be similar for seven days and 28 days properties.

4.3 Split Tensile Strength

Cylinder specimens were tested for splitting tensile strength. The test was carried out according to IS: 5816-1970. The variation in the splitting tensile strength of various concrete mixtures over plain concrete is also shown in Fig 3. The increase in Split Tensile strength of concrete with normal coarse aggregate (NCA) with 0.2%, 0.3% and 0.4% PP fibre was observed to be 17%, 4% and 13% respectively when compared to plain concrete. For concrete mix with 50% RCA, the increase in strength with the addition of PP fibres was observed to be 6%, 2% and -4% respectively when compared to NCA concrete. For the grades of concrete M-60 with 0, 50 and 100% RCA there is a maximum increase in the splitting tensile strength at 0.2% of fibre with the percentage increase 17%, 6%and 4% respectively. But when RCA completely replaced NCA at higher dosages of fibre, a decrease in strength of 12% was observed.

4.4 Flexural Strength

Prism specimens were tested under two-point loading at the age of 7 and 28 days and strengths are shown in Fig 4. There is a marginal increase in strength of M-60 grade concrete with NCA and PP fibre of 0.2%, 0.3%and 0.4% when compared to plain concrete. Similar trend was observed for 50% RCA also while for 100% RCA, a large reduction in flexural strength of about 26% was observed for all PP fibre percentages owing to fibre balling and lesser strength of aggregate.

4.5 Secant modulus of elasticity

Concrete cylinders were tested for Secant modulus. The tests were carried out confirming to IS:516-1959. The variation in modulus of elasticity of various concrete mixtures over the plain concrete is shown in the Fig 5. The observed values are coinciding with observations made by several researchers around the globe.

4.6 Ductility Characteristics

The PP fibre induced prisms exhibited a little ductility characteristics with the appearance of crack before failure. At the failure load, a crack appeared in between the loading points and then specimens failed. It was also observed that with the

percentage increase in the addition of PP fibre content from 0.0% - 0.4%, there was a decrease in deflections for the same load (Fig 6-8) indicating improved flexural stiffness of the beams.

5. CONCLUSION

The experimental results show that there is a slight decrease in workability with the use of recycled coarse aggregate and also with the addition of fibres. There is a marginal decrease in the strength of concrete as 50% of conventional coarse aggregate is replaced with recycled coarse aggregate. But in both these concretes (Natural aggregate and Recycled aggregate) the strengths were found to increase with the increase in fibre content up to 0.2% of PP 3S fibre. It is observed that the strengths for concrete were continuously decreasing, even after adding the PP fibres, for concrete with 100% recycled aggregates. However, use of recycled aggregates upto 50% by weight of natural aggregates achieved required strength confirming the suitability of their use in high strength concrete of grade M60. The addition of polypropylene fibres improved the stiffness of the concrete while imparting ductility.

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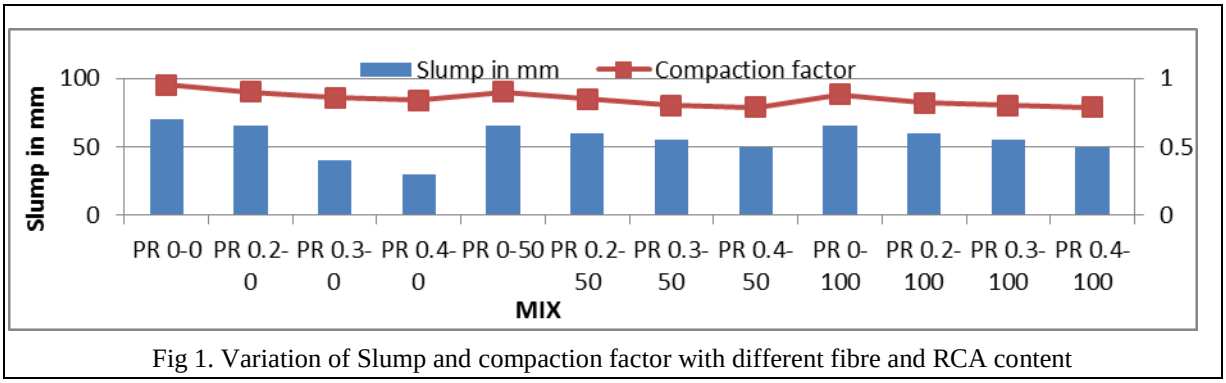

Fig 1. Variation of Slump and compaction factor with different fibre and RCA content

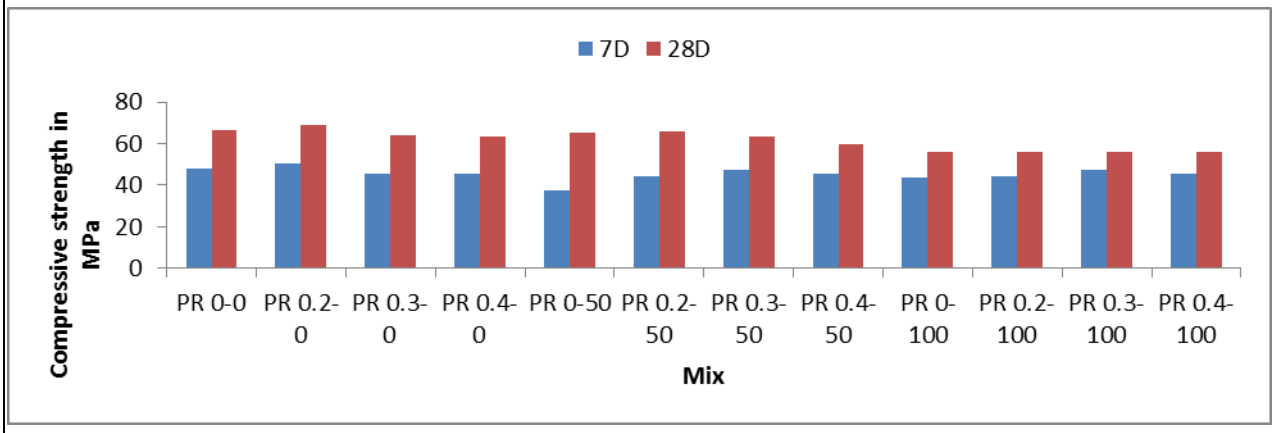

Fig 2. Variation of Compressive Strength with different fibre and RCA (0, 50, 100%) content

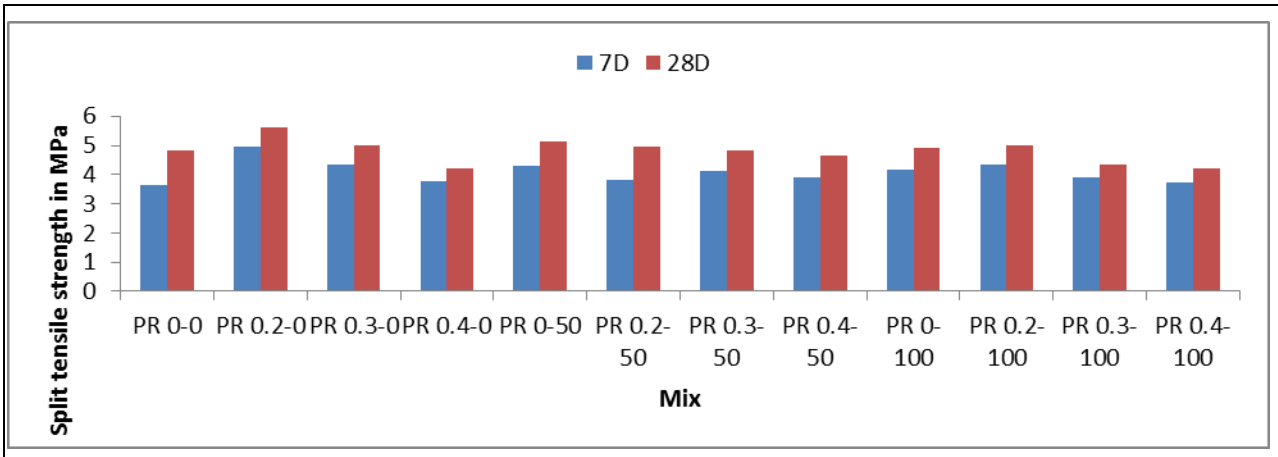

Fig 3. Variation of Split Tensile strength with different fibre and RCA (0, 50, 100%) content

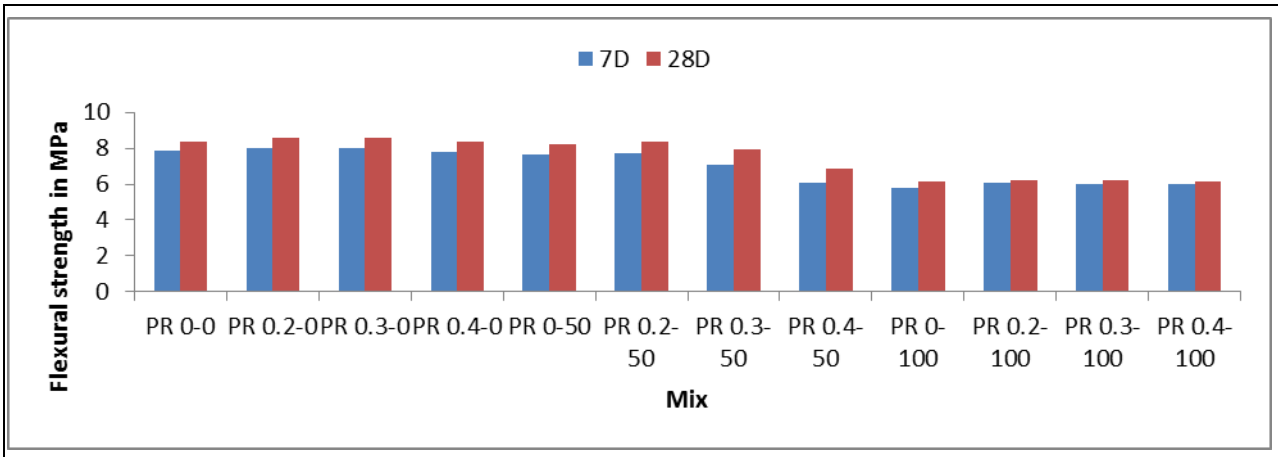

Fig 4. Variation of Flexural Strength with different fibre and RCA (0, 50, 100%) content

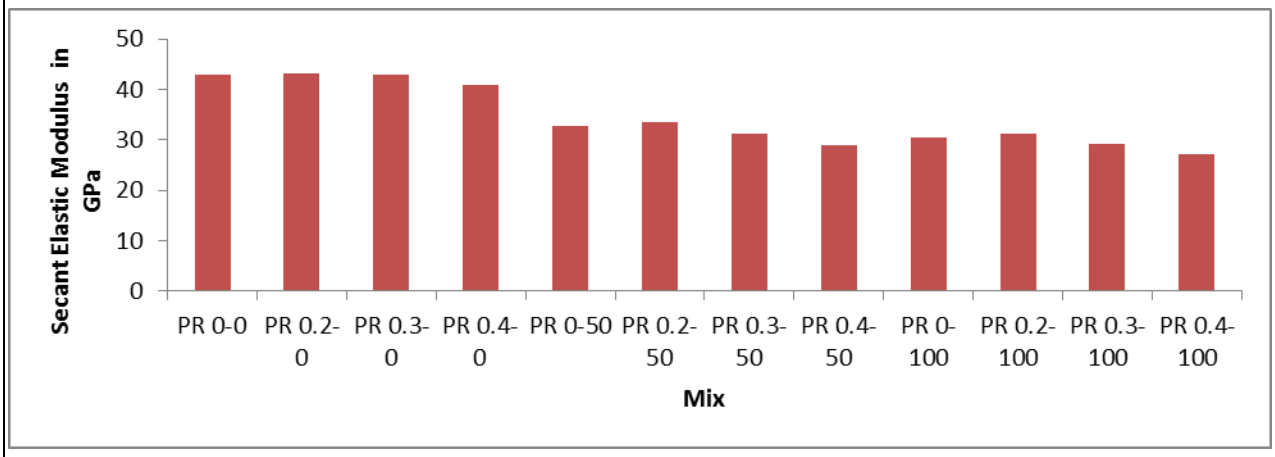

Fig 5. Variation of Static Modulus of Elasticity with different fibre (0,0.2,0.3,0.4%) and RCA (0, 50, 100%) content

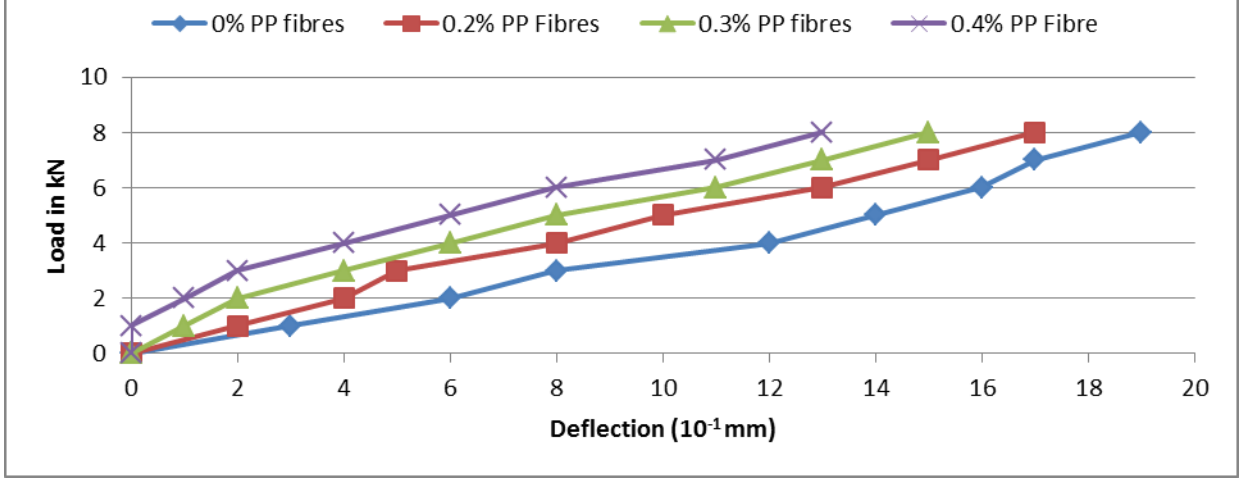

Fig 6. Variation of Deflection with load for 0% RCA for different percentage of PP fibres

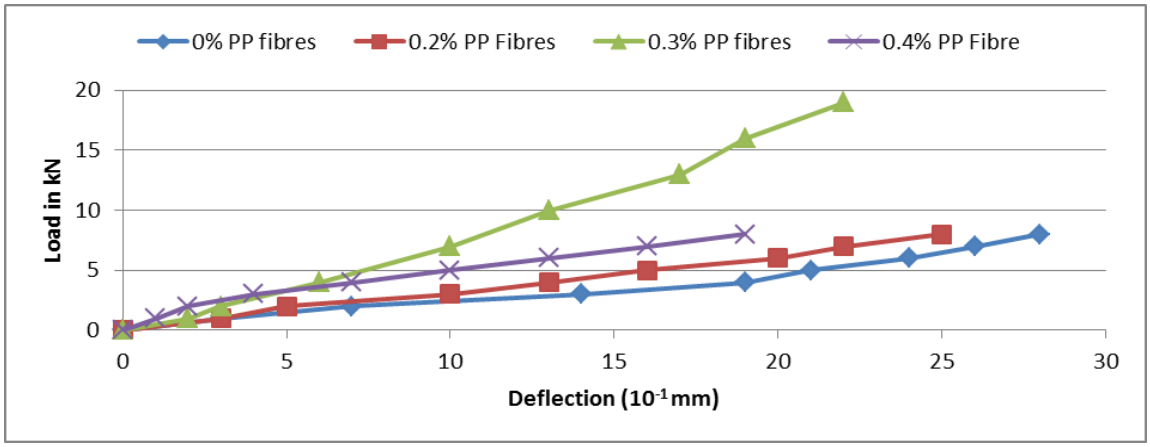

Fig 7. Variation of Deflection with load for 50% RCA for different percentage of PP fibres

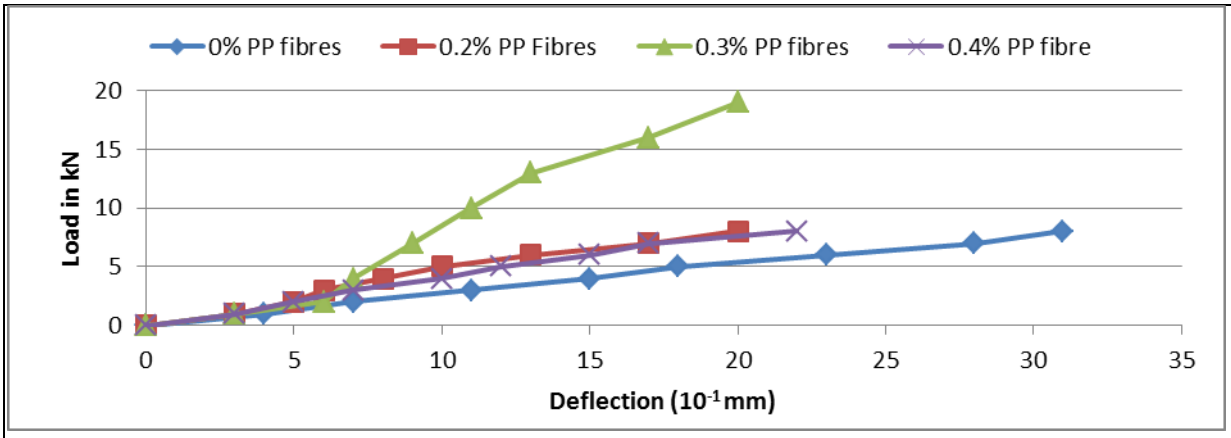

Fig 8. Variation of Deflection with load for 100% RCA for different percentage of PP fibres

Plate 1. Raw Recycled aggregate and Laboratory Jaw Crusher

a. Cylinder

b. Cube

Plate 2. Compression Test on concrete Specimens

Plate 3. Flexure Test Set-up in UTM

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Study of Various Column Geometries Influence on Structural Design

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Abstract--Column is the most critical member of a structure as its failure may lead to collapse of the whole structure. Present research is carried out to study the effect of column cross section geometry on various design control parameters. A 10 storey structure is designed for gravity loads and seismic loads using square shaped columns. The same structure is analyzed and designed using circular, rectangular and a combination of +, L and T shaped columns with same cross sectional area as that of square shaped columns. A comparative study is made to check the variation in base shear, deflection and stiffness of the structure with various column geometries. Study is also made to compare various parameters for individual column.

***Keywords*—Column cross section, Base shear, Stiffness, Moment of inertia, Deflection.**

I. INTRODUCTION

A structure is subjected to gravity load which include the dead load and live load acting on it and also lateral loads like wind load and seismic load. These loads increase as the height of the structure increases resulting in requirement of larger cross section of column. These larger sections reduce the working space and hence are uneconomical. Moreover the aesthetic view of the spaces will be lost due to presence of these protruding columns. In the present scenario all the metropolitan cities need to construct high rise structures to meet the requirements of growing population. Hence there is a greater need for proper designing of structure which is safe and economical. To ensure this the conventional construction and design practices should be modified with the new techniques which provide a solution to present day challenges.

Some of the special construction techniques such as adopting special shaped columns behave safe and economical than compared with the conventional square or rectangular or circular shaped columns. In case of special shaped columns, the cross sectional area can be dispersed away from the neutral axis can help in increasing the moment of inertia thereby increasing the flexural stiffness.

L-shaped, T-shaped and + shaped columns are some specially shaped columns which have equivalent area as that of conventional column section but an increased moment of inertia about the centroidal axis.

In the multi-storey structure and high rise residential system, the application of specially shaped columns has the many advantages such as avoiding the prominent corners in the rooms, providing convenience in construction layout, increasing the usable area and more economy. The + shaped column can be used at the cross intersections of beams which is capable of carrying more loads than compared with conventional square, rectangular or circular columns. The choice of column shape depends upon on various factors such as the loading condition, adequacy for space, architectural requirements etc. It has been often found that to make the column safe, larger dimensions than actually required are provided to account for all the loading conditions. But the fact is that if we properly adjust the cross section of the column according to the requirement, much economy can be achieved.

To study the displacement capacity of a single column with various cross sections, a single column is modelled in SAP-2000. The area of cross section and the reinforcement in all the geometries (+, L, T, square, circular and rectangular) is kept constant. The support conditions provided are, the base is fixed and top end if free. An incremental lateral load was applied at the top end and the displacement capacity is studied for all the cross sections.

To compare various design control parameters under gravity and seismic loads a case study is carried out by considering a 10 storey shown in figure 8 and response spectrum analysis is carried out by using SAP 2000. The study concludes by comparing the parameters such as base shear, stiffness, area of reinforcement and top storey displacement of the structures with various column cross sections. In the case of + shaped columns more area is dispersed away from centroidal axis which increase the moment of inertia, table G shows the comparison with conventional square shaped column.

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The increase in moment of inertia contributes to increase in flexural strength capacity which helps in decrease in area of reinforcement.

II. Literature Review

Mishra, et al.[1] in 2015 made an attempt to compare the response reduction factor values given in IS code and ACI code using the specially shaped columns. The study concludes with the tabulated results of response modification factors for different structures incorporating specially shaped columns and conventional columns. Yang et al.[2] in 2008 published a technical specification by considering framed structure with rectangular columns and specially shaped columns and are designed respectively based on the criterion of same sectional area, same moment of inertia and same initial stiffness. This study concludes that the structures comprising of specially shaped columns could resist the earthquake effectively than compared with the conventional columns. Wang and et al.[3]in 2014 conducted an experimental research on a cross shaped columns to estimate the failure modes, bearing capacity and displacement ductility using 500MPa grade of reinforcing steel bars. Cyclic loads were applied on the cross shaped column to study the ductility parameters. The study finally concluded that on using high strength reinforcing steel for stirrups could help in confining the core concrete and decreasing the spacing was effective in increasing the ductility, bearing capacity and displacement ductility.

Agrawal and Pajgade[4]in 2015 discussed a review on reinforced concrete buildings with specially shaped column and RC building with shear walls. Specially shaped columns avoid prominent corners in a room which increases usable floor area. Wang and et al.[5]in 2014 conducted an experimental research on a L shaped columns to estimate the failure modes, bearing capacity and displacement ductility using 500MPa grade of reinforcing steel bars. Cyclic loads were applied on the cross shaped column to study the ductility parameters. Wang and Ni [6] in the year 2013, suggested some optimization techniques to increase the performance of the structures with specially shaped columns so as to increase the ductility of the structure and the energy dissipation capacity.

Ductility has to be guaranteed both for the structure and for the members. Incorporating the structural systems could help in increasing the ductility.

The dynamic analysis is carried out by using the software package SAP-2000 (Computers and structures)[7].The other parameters such as zone factors, importance factors are referred from the Indian Standard Codes i.e. IS 456-2000 (Code of Practice for Plain and Reinforced Concrete)[8] and IS 1893-2002 (Criteria for Earthquake Resistant Design of Structures Part 1: General Provisions and Buildings,)[9].

III. Modelling And Analysis

A. *Single Column Analysis*

A single column with different cross sections was modelled in by using SAP-2000 (Computers and Structures, Inc.) shown in figure 1. The area of cross section and the reinforcement in all other geometries (+, L, T, square, circular and rectangular) is kept constant. The cross sectional dimensions are given in table A. The base of the column is fixed and the top end is free. An incrementing lateral load is applied in addition to gravity load at the top end and deflections are noted.

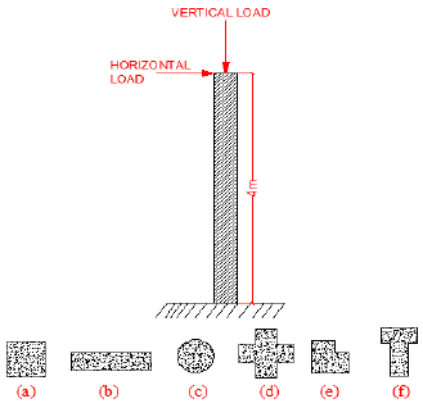

Figure 1. Single column analysis with different cross sections.

In table A it is observed that the specially shaped columns contains flange and web, which helps in reducing the deflections of column in the case of lateral loads. The lateral load is applied in both the directions so as to check the deflection of unsymmetrically shaped columns such as rectangular, T and L shaped columns. The plus shaped column is expected to show the least value of deflection compared to other geometries.

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TABLE 1
CROSS SECTIONS ADOPTED FOR SINGLE COLUMN ANALYSIS.

S. No.	Column Cross Section	Area of cross section	Thickness of flange and web
(a)	Square shaped column	600 x 600mm	-
(b)	Rectangular shaped column	300 x 1200mm	-
(c)	Circular shaped column	677.02mm (Dia)	-
(d)	+ shaped column	750 x 750mm	300mm
(e)	L shaped column	487.5 x 487.5mm	300mm
(f)	T shaped column	600 x 900mm	300mm

B. Structural Analysis

Four separate structures, first with square columns (shown in figure 3), second with rectangular columns (shown in figure 5), third with circular columns (shown in figure 4) and fourth with mixed columns (+, L & T) (shown in figure 2), were modelled. First the 10 storey structure is designed using square columns and the amount of steel in each column is noted. Other three structures are modelled with different cross sections (circular, rectangular, +, L &T) of columns maintaining equivalent area of cross sections and same area of reinforcement at respective places as that of a structure with square columns. [8]Response spectrum analysis is carried out to compare the various parameters among the four structures.

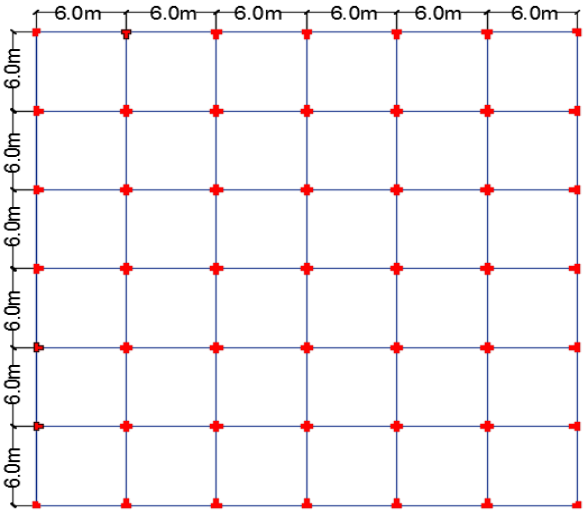

Figure 2. Layout of structure +, L and T shaped column.

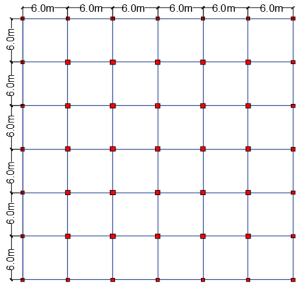

Figure 3. Layout of structure square shaped columns.

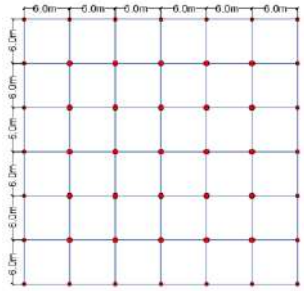

Figure 4. Layout of structure with circular shaped columns.

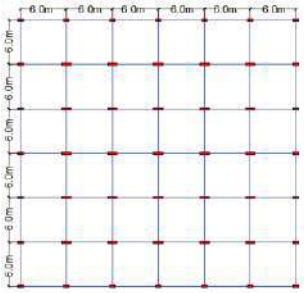

Figure5. Layout of structure with rectangular shaped columns.

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Plus shaped columns are used at all intermediate junctions of the beams, L columns are used to replace the square shaped columns at corners and T shaped columns are used to replace the square shaped columns at all four edges of the structure (shown in figure 2,3,4&5) .

The dimensions of exterior columns were kept less compared to the dimensions of interior columns, which is explained in table B and table C. The reinforcement also varies which is shown in figure 6 and figure 7.

TABLE 2.
DIMENSIONS OF EXTERIOR COLUMNS.

S. No.	Column Geometry	Size of Column
(a)	Square Shaped Column	450 x450mm
(b)	Rectangular Shaped Column	300 x 675mm
(c)	Circular Shaped Column	507.77mm (Dia)
(d)	L Shaped Column	487.5 x487.5mm
(e)	T Shaped Column	337.5 x 300mm

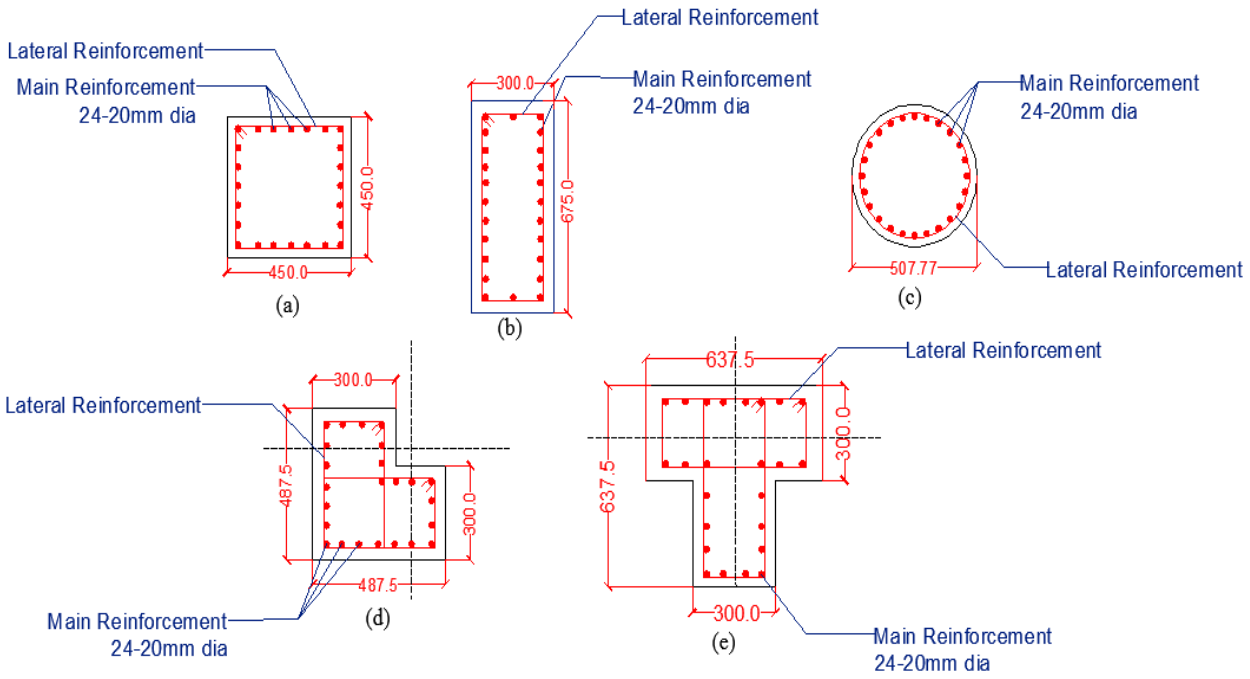

Figure 5. Specifications of Exterior Columns.

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TABLE 3.
REINFORCEMENT DETAILS OF EXTERIOR COLUMNS.

Longitudinal reinforcement	24No's 20mm diameters bars
Lateral reinforcement (ties)	8mm diameter lateral ties at 150mm c/c
Clear Cover	40mm

TABLE 4.
DIMENSIONS OF INTERIOR COLUMNS

S. No.	Column Geometry	Size of Column
(a)	Square Shaped Column	600 x 600mm
(b)	Rectangular Shaped Column	300 x 1200mm
(c)	Circular Shaped Column	677.02mm (Dia)
(d)	+ Shaped Column	750 x750mm

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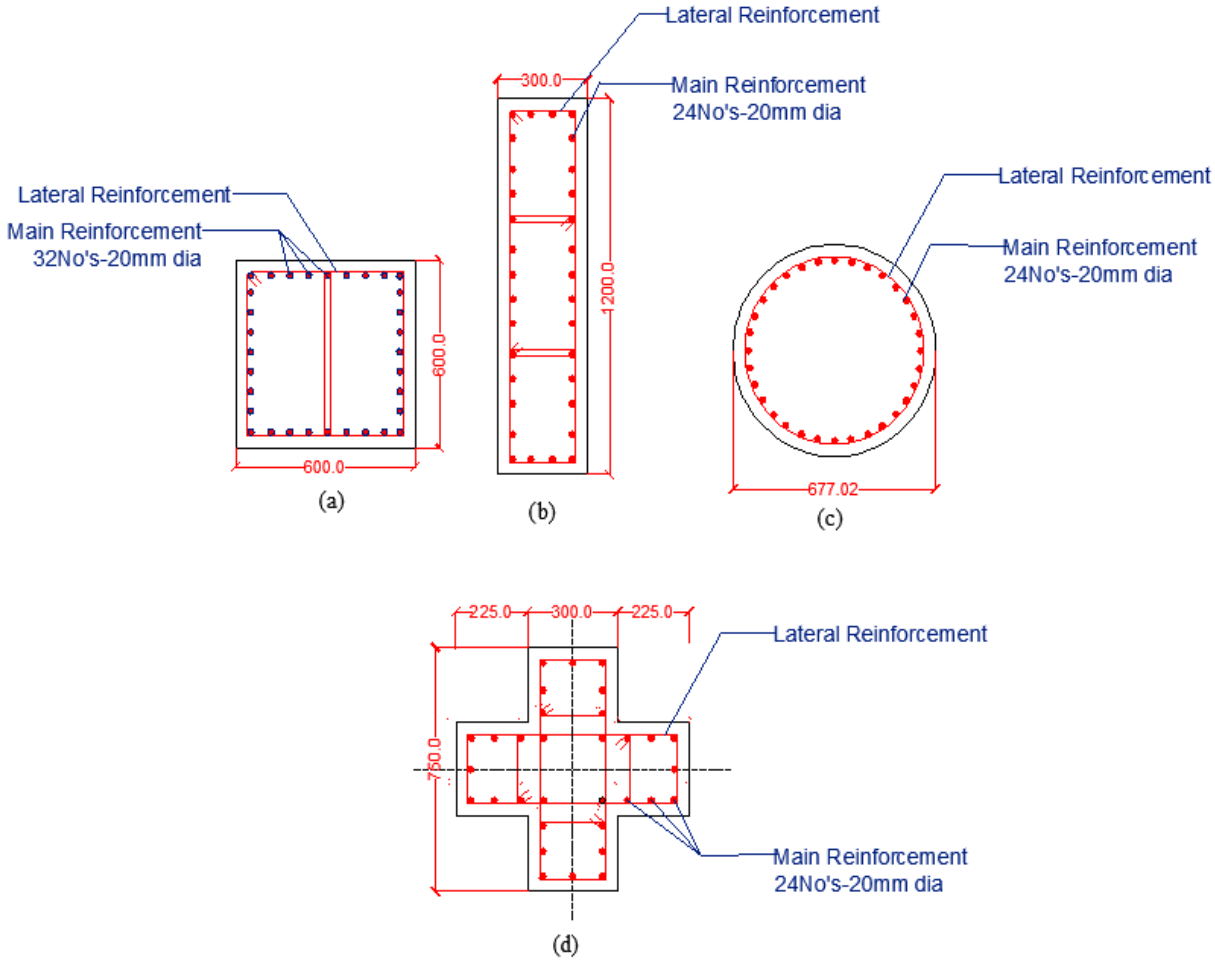

Figure 6. Specifications of Interior Column.

TABLE 5
REINFORCEMENT DETAILS FOR INTERIOR COLUMNS.

Longitudinal reinforcement	32No's 20mm diameters bars
Lateral reinforcement (ties)	8mm diameter lateral ties at 150mm c/c
Clear Cover	40mm

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TABLE 6
MODEL SPECIFICATION

Grade of Concrete	M30
Grade of steel	Fe500
No. of storeys	10 storeys
Span in X-direction	6m
Span in Y-direction	6m
Height of each floor level	4m
Beam dimensions	0.23 X 0.55m (including slab thickness)
Building Height	42m (including plinth level)
Type of building	Bare framed RC model

The TABLE and Figure 7 describe the specifications of model used to perform response spectrum analysis. The structure was analyzed by response spectrum method using SAP-2000. The lateral load distribution generated respond to the seismic zone 4 and default damping of 5% as given by IS 1893:2002.

Figure 8 and Figure 9 were modelled to determine the amount of reduction in area of reinforcement required, by comparing the structures comprising of square and mixed columns. As the central column carries more gravity load, it is considered for the calculation of area of reinforcement required in both the structures.

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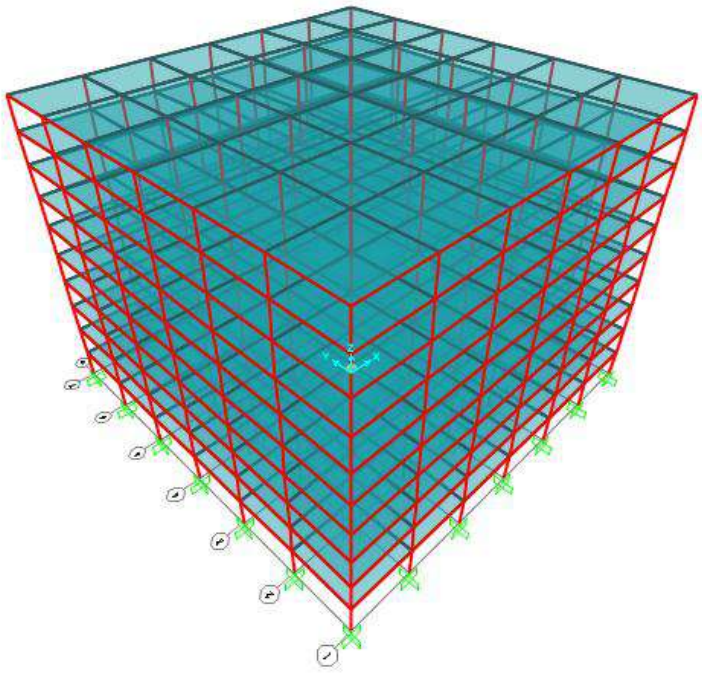

Figure 7. 3D model of the structure.

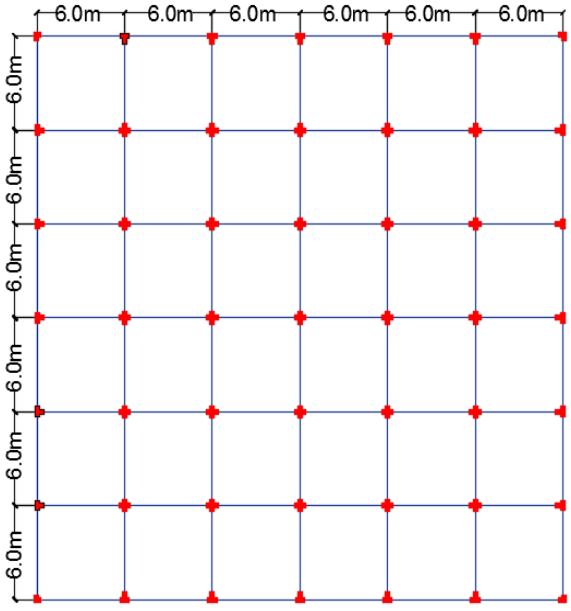

Figure 8. Layout of structure +, L and T shaped column.

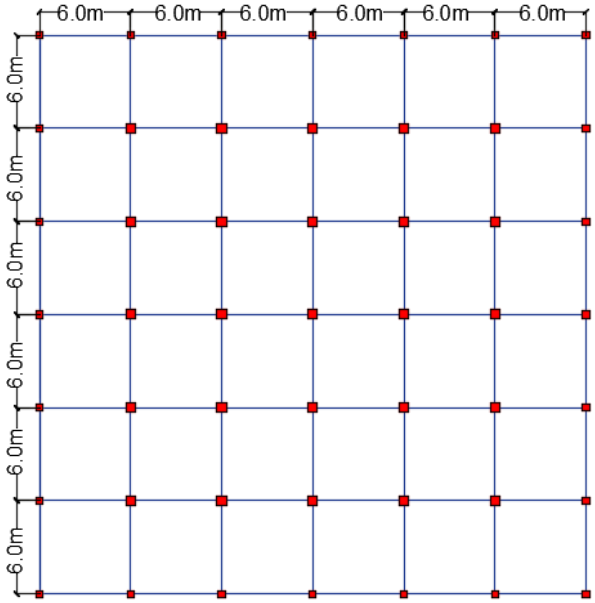

Figure 9. Layout of structure with square shaped columns.

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IV. Discussion Of Results

C. Single column results:

Dispersing more area away from the centroidal axis increases the moment of inertia, by maintaining the same area of cross section for + shaped column as that of a square column the moment of inertia can be increased by about 20% shown in TABLE .

As the moment of inertia is increasing, the stresses induced will be less and the load carrying capacity and the moment carrying capacity will increase.

Moreover, if we want to design the column for the same designed load and moment as required for the square section, then the dimensions of the + shaped column will reduce i.e. the amount of material required will be less.

It is observed from the single column analysis that the + shaped column deformed less as compared to other cross sections. From Figure 10 it can be observed that the deflection for + shaped column is less than compared to square, rectangular, circular columns. The rectangular column is analyzed in both the directions. T shaped column also shows less deflection at the top than compared with other column geometries.

TABLE 7
COMPARISON OF MOMENT OF INERTIA FOR SQUARE SHAPED COLUMN AND + SHAPED COLUMN.

Square shaped section	+ shaped section
Area = 600 x 600 = 360000mm^2	Area = 360000mm^2
Moment of inertia: Ixx = Iyy= (600^4) /12 = 1.08 x 10^{10} mm^2	Moment of inertia: Ixx = Iyy = 2.97 x 10^{10} mm^2 Increased by 20%

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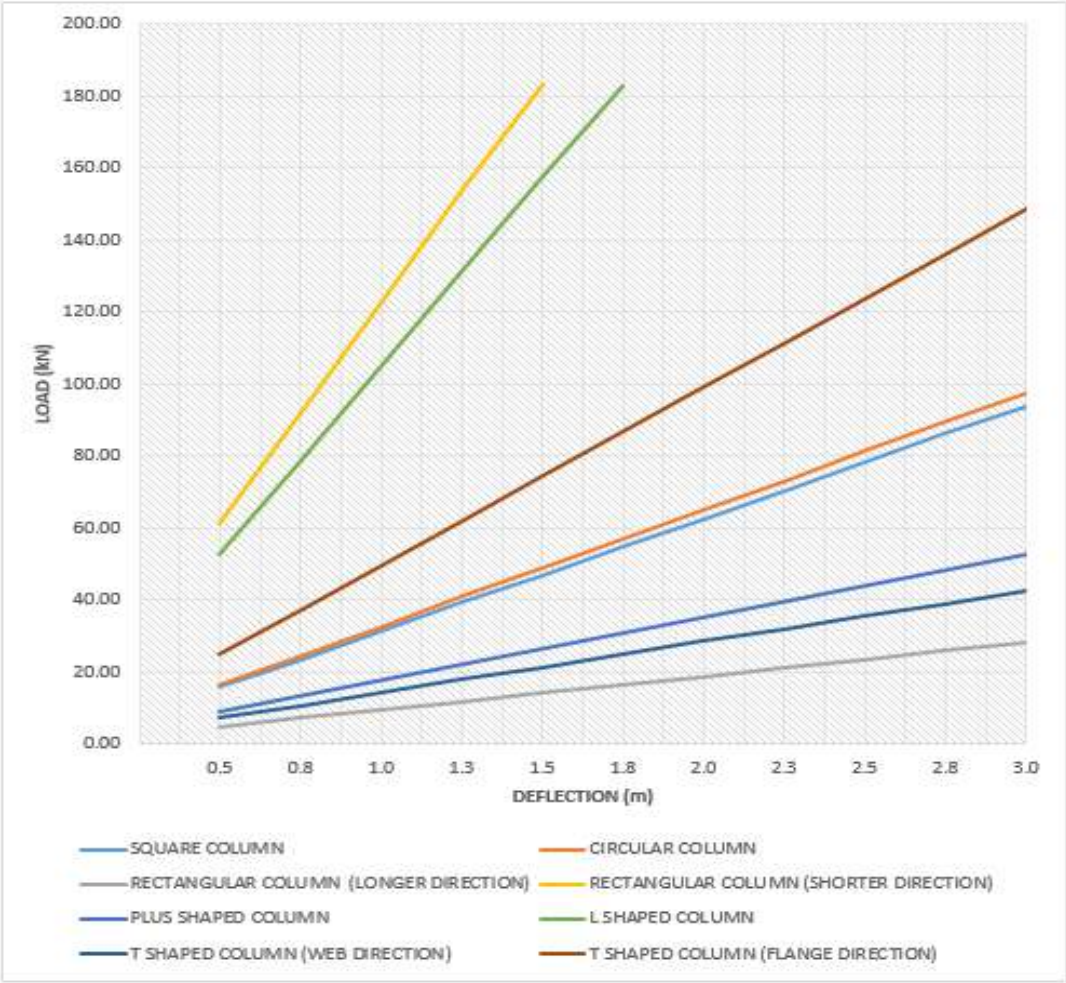

Figure 10. Displacement capacity for different column cross sections.

A. Structure Results

Table 8.
BASE SHEAR COMPARISON FOR STRUCTURES WITH DIFFERENT COLUMN GEOMETRY.

Column geometry	Base shear (kN)
Square column	1505.24
Rectangular column	2072.36
Circular column	1266.78
Mixed column	1106.5

The base shear in the case of the structure with mixed shaped column is decreased by 26.4% compared with the conventional square shaped column. As the base shear is reduced, the deformation of the structure due to lateral load is decreased. Table shows the tabulated results of base shear for structures with different column geometries.

Stiffness in the case of mixed columns was found to be increased by 11.9% than compared with the conventional square columns. Figure 11 shows the stiffness in the case of structures with different column cross section. As the moment of inertia increases the stiffness of the structure increases. This helps in reduction of deformations for the lateral loads.

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Figure 12 shows the top storey deflections of the structure when subjected to gravity loads and lateral loads in both the directions, the deflection in the case of mixed columns structure and the conventional columns structure are within the IS code limits.

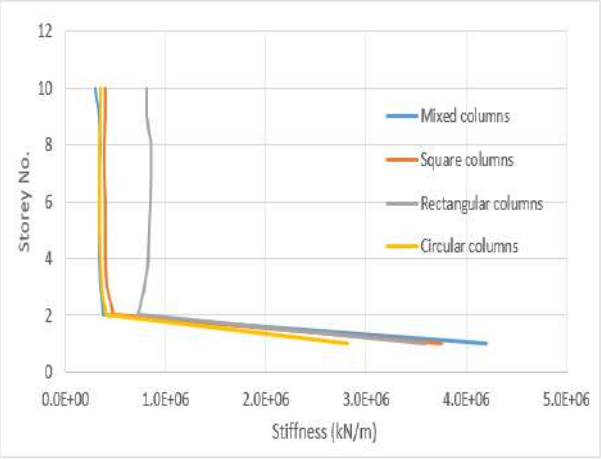

Figure 11. Plot between stiffness and storey for different structures modelled on SAP-2000.

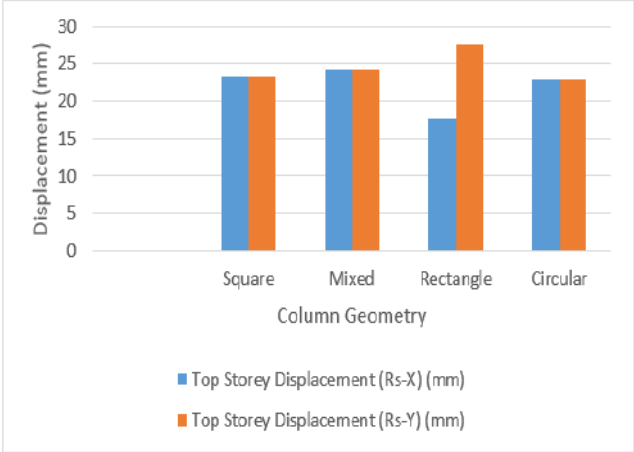

Figure 12. Top storey displacement of the structures with different column cross sections.

TABLE 9.
COMPARISON OF STEEL QUANTITIES FOR SQUARE COLUMN AND + SHAPED COLUMN

Square Shaped Column				+ Shaped Column						
Floor Level	Cross section (mm)	Area of steel (mm^2)	Amount of steel (kg)	Cross section	Area of steel (mm^2)	Amount of steel (kg)	Decrease in area of steel compared to square column	Percentage decrease in area of steel	Decrease in quantity of steel (mm^2)	Percentage decrease in Quantity of steel per column
Below Plinth	600 x 600	10094	118.857	750 x 750	7815	92.03	2279	22.5800		
G.F		8319	261.217		7634	239.71	685	8.2400		
1		6096	191.414		5655	177.57	441	7.2400		
2		4009	125.883		3705	116.34	304	7.5900		
3		2880	90.432		2852	89.56	28	0.9800		
4		2880	90.432		2852	89.56	28	0.9800		
5		2880	90.432		2852	89.56	28	0.9800		
6		2880	90.432		2852	89.56	28	0.9800		
7		2880	90.432		2852	89.56	28	0.9800		
8		2880	90.432		2852	89.56	28	0.9800		
9		2880	90.432		2852	89.56	28	0.9800		
Total amount in kgs			1330.39			1252.57			77.83	5.9

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To compare the amount of steel required a column was designed form top storey to bottom storey with square and + shaped cross sections. It was observed that the amount of steel required reduced by about 6% by using the + shaped cross sections shown in table I.

V. CONCLUSION

- From single column analysis the deflection of + shaped column was found to be reduced by 46.2% in comparison with other columns. As the area is dispersed away, more stability is obtained which helps in reduction of deflection.
- Moment of inertia of + shaped column was found to be increased by 20% compared with square column for the same area of cross section, which contributes to increase in stiffness and decrease in deflections.
- Base shear is reduced by 36% for the structure with mixed columns (+, L & T), compared to the structures with other geometries. Hence more lateral loads can be resisted with less deformations.
- Stiffness is increased by 11.9% for the structure when mixed columns (+, L & T) cross sections are used compared to other structures with conventional columns.
- Required area of reinforcement for + shaped column is reduced by 6% compared to the square column for the same loading conditions.
- Top storey displacements in both the directions for mixed columns structure are within the limits.

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Studies on SCC Using Processed and Unprocessed Recycled Aggregate

N Srikanth, N R Dakshina Murthy, M V Seshagiri Rao

Abstract

Self Compacting Concrete (SCC) is a special type of concrete which flows and consolidates by its self weight, thereby eliminates the problems of placing in difficult situations such as congested reinforcement and thinner sections. In recent years the demand for construction materials has grown tremendously and a large amount of demolition waste is being generated, which is creating an environmental pollution. The major component of concrete is aggregate which constitutes about 70-80% of total components so it will be beneficial to recycle the aggregate for construction works and also to solve the environmental problems. It is estimated that the construction industry in India generates about 10-12 million tonnes of demolished concrete annually. This has encouraged the use of recycled coarse aggregate which reduces environmental pollution to a greater extent on one hand and saving of natural resources on other hand. By using the recycled aggregate the consumption of natural aggregate can also be reduced. An attempt has been made to produce SCC using RCA. In the present study the experiments were carried out on M35 and M45 grade of concrete under self compacting conditions. The self compacting properties for the present grades of concrete were evaluated using EFNARC 2005 specifications. The natural coarse aggregate was replaced at 0%, 25%, 50%, 75% and 100% by recycled coarse aggregate (RCA) in unprocessed and processed (500 and 1000 revolutions in Deval's Abrasion)state. Fresh properties such as Slump, V-funnel and L-box for SCC were determined for various percentage replacement levels of recycled coarse aggregate. The hardened properties such as compressive strength, split tensile strength were determined. The non-destructive test such as rebound hammer was used to evaluate compressive strength. The unprocessed and processed (500 revolutions and 1000 revolutions) test results were compared to get the optimum replacement level of recycled coarse aggregate (RCA).

Keywords : Self Compacting Concrete (SCC), Recycled coarse aggregate (RCA), Superplasticizers (SP), viscosity modifying agents (VMA), Natural Coarse Aggregate (NCA).

Introduction

Concrete is the premier construction material used across the world and it is mostly widely used in all types of civil engineering works including infrastructures, low and high rise buildings, defence installations, environmental protection structures etc,. Presently construction industry is making strides all around the globe. New materials and new construction techniques are coming up in order to reduce the manpower in construction industry. Self compacting concrete (SCC) is a special concrete tailored to overcome the problems of compacting in case of dense reinforcement and thin sections. The Concrete can able to flow by its self weight and thereby filling the form work achieving full compaction. The hardened SCC has similar properties as that of traditional vibrated concrete from strength and durability aspects. Thus SCC is proved to be a good concrete which improves the overall performance of the concrete structure. As far as Indian scenario is concerned lack of specifications in terms of SCC production is also creating confusion among the researchers and structural engineers who are working in this specified area.

It is estimated that the construction industry in India generates about 10-12 million tonnes of demolished concrete annually. The quantum of demolished concrete has increased by a greater extent due to urbanization and this has created a need to use the coarse aggregate which is the major component in the concrete material. Akbari et al [1] investigated on Self Compacting Concrete Using Recycled Coarse Aggregate and concluded that the mixes containing recycled coarse aggregate gains quick early strength due to presence of partially hydrated cement adhered to coarse aggregate which accelerates the hydration process. Most of the research was carried out on the use of recycled coarse aggregate in unprocessed state. Shahil M.Bandi et al [2] in their technical paper discussed that RCA show higher water absorption compared with conventional NCA due to old mortar attached with original concrete and has relatively lower specific gravity. Sai Krishna Mohan Chowdary[3]

observed through experimental investigations that the Use of RCA in SCC not only reduces the environmental pollution but also provides an economic value for the RCA. Nataraja et al [4] in their discussion on-performance of recycled aggregates in self compacting concrete mentioned that as the percentage of RCA increases, the dosage of SP also increases to maintain a constant slump. Jitender Sharma et al[5] in his technical paper suggested that new standards should be introduced for recycled aggregates so that these materials can be used successfully in future. The fresh properties of SCC such as surface texture, flow ability can be improved by processing of aggregate. Therefore SCC using RCA has to be designed to meet the requirements of the future demand thereby reducing environmental pollution and also to maintain sustainability of natural resources. Processing of RCA will not only improve the flow ability characters but also enhances the mechanical properties such as compressive strength, split tensile strength etc. Prashant O. Modani et al [6] observed that recycled aggregate can be effectively used in the production of SCC without any significant reduction in strength and durability. This has encouraged the use of recycled aggregate in concrete which not only allows for a more efficient life cycle of natural resources but also contributes to environmental protection leading to sustainable development. Recycled aggregate has rough – textured, angular and elongated particles where as natural aggregate is smooth and rounded compact aggregate. RCA aggregates tend to be very angular and rough due to the crushing of the virgin aggregate particles and the presence of cement paste that continues to cling to the surfaces of the aggregate. Sumanth Reddy et al [7] conducted experimental investigation on SCC using processed RCA and concluded that Processing of RCA is beneficial since the performance is being improved but a balance is to be attained between extent of processing and required properties because of energy and cost of processing. Significant potential is there to utilize the recycled aggregate for the production of SCC all over the world. It's a 'green' solution for anticipated world. Natural resources are limited. There is a global need to protect our environment and preserve our scarce natural resources for next generations. Recycling of Construction &Demolition materials can help preserve our public fill capacity and precious landfill space. It can also help to reduce the need for quarrying and damage to our natural landscape. Panda et al [8] in their studies on SCC using RCA mentioned SCC marginally achieves required compressive strength up to 30% replacement of RCA on further increase compressive strength may decrease. Dabhade et al [9] in his observations on RCA concrete, the Usage of recycled aggregates can not only preserve the finite raw materials, but also reduce energy consumption and overall construction costs. Nataraja et al [10] in their discussion on strength behaviour of self compacting concrete mixes using local materials mentioned that even 300 kg cement per m^3 has a potential to produce concrete having strength in the range of 25 to 40 MPa depending on the w/c ratio with suitable dosage of SP. The self compacting properties for the present grades of concrete were evaluated using EFNARC specifications[11]. Surface texture, shape of the aggregate will play an important role in developing the self compacting properties of aggregate. In terms of morphological characteristics, recycled aggregate is less favorable than natural aggregate. The grains are irregular, mostly with angular shape, rough and with cracked surface and porous. This grain characteristics significantly affect the workability of fresh concrete, as well as the permeability of liquids and gases in the hardened state; they also significantly depend on the properties of concrete used in recycling for production of aggregate, especially its strength, porosity, exploitation conditions to which it was subjected, but also on the ways and levels of recycling – the type of applied crusher and possible additional processing procedures.

The size, shape, and texture of aggregate particles are important because these physical characteristics influence the engineering properties. Recycled organic aggregates have advantageous physical and mechanical properties for geo engineering applications, but the particle shapes and textures have not been well quantified and evaluated.

Materials and Mix Design

1. Material Properties

Cement

Ordinary Portland cement of 53 grade was used for the experimental investigation which is confirming to IS: 269-2015. The Physical properties of cement are shown in Table-1.

Fly Ash:

Fly ash used for the experimentation was brought from Vijayawada thermal power station (VTPS) in Andhra Pradesh and confirmed to Class-F Flyash. Physical properties of Flyash are shown in Table-2.

Aggregates:

Coarse Aggregate is of locally available crushed granite from quarries and fine aggregate used was obtained from nearby river source. The Physical properties of

natural and recycled coarse aggregates are shown in Table-3. The Physical properties of fine aggregates are shown in Table-4. The Properties of chemical admixtures such as Super plasticizer and Viscosity Modifying Agent are as per CAC Chemicals listed in Table-5 and Table-6.

Table 1 Physical properties of cement

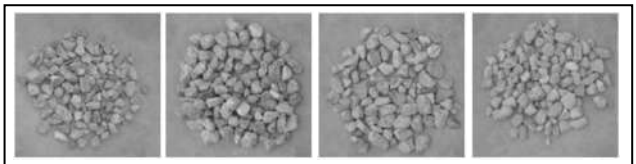
S.No	Properties	TestResults
1	Standard consistency	32%
2	Specific gravity	3.10
3	Initial setting time	45min
	Final setting time	192 min
4	Fineness of Cement	240 m^2/kg

Table 2 Physical properties of class F flyash

S.No	Characteristics	Properties
1	Specific gravity	2.3
2	Specific surface area	420 m^2/kg

Table 3 Physical properties of coarse aggregates

Properties	Natural Coarse Aggregate		Recycled Coarse Aggregate	
	10mm	20mm	10mm	20mm
Specific Gravity	2.6	2.7	2.8	2.6
Bulk Density (g/cc)	1.49	1.61	1.44	1.42
Fineness Modulus	6.45	7.3	6.5	6.9
Impact Value	20	21	13.3	13.8



Natural Aggregate | Unprocessed Recycled Aggregate | Processed Recycled Aggregate (500 R) | Processed Recycled Aggregate (1000 R

Table 4 Physical properties of fine aggregates

Properties of Fine Aggregate	Test Results
Specific Gravity	2.62
Bulk Density (g/cc)	1.5
Fineness Modulus	3.1

Table 6 Properties of Viscosity Modifying Agent (As per CAC Chemicals)

S.No	Property	Result
1	Form or State	Liquid
2	Colour	Colourless
3	Specific gravity	1.01 ± 0.02 at 30°C
4	Chloride content	Nil
5	pH	Min 6
6	Dosage	0.05 to 0.5 litres per 100kg of cement

Table 5 Properties of Super plasticizer (As per CAC Chemicals)

S. No	Property	Result
1	Form or State	Liquid
2	Colour	Brown
3	Specific gravity	1.22. to 1.225 at 30°C
4	Chloride content	Nil
5	Air entrainment	Approx. 1%
6	Dosage	0.5 to 1.2 litres per 100 kg of cement
7	pH	Min 6

2. Mix Design

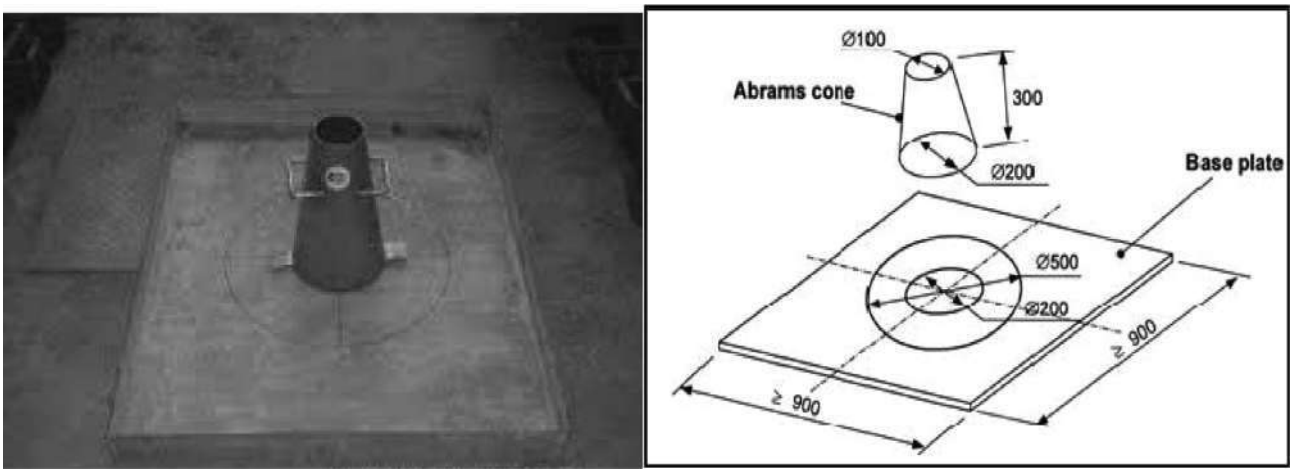
The mix proportions for SCC with RCA satisfying all the fresh and hardened properties as per EFNARC-2005 specifications[11] were attained after a number of trail mixes. The mix design was carried out as per Nan su et-al method. A number of trial mixes were attempted by varying ratio of total aggregate to fine and coarse aggregate, varying dosage of chemical admixtures, powder content and recycled coarse aggregate to get the desired properties of SCC and the same were investigated. 39 Number of cube specimens and 39 Number of cylinders for M35 and M45 grade of concrete were cast (total 78 Cube specimens and 78 cylindrical

Final Mix proportion satisfying EFNARC specifications for M35 grade of concrete is 1 :1.72 :1.56 :0.37

Grade of concrete	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Fly Ash kg/m^3	Water kg/m^3	SP lt/m^3	VMA lt/m^3
M_{35}	373	880	802	135	188	5.5	0

Final Mix proportion satisfying EFNARC specifications for M45 grade of concrete is 1 :1.73 :1.52 :0.352

Grade of concrete	Cement kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Fly Ash kg/m^3	Water kg/m^3	SP lt/m^3	VMA lt/m^3
M_{45}	395	899	792	122	182	5.68	0



Slump flow test equipment *(Courtesy from civil-online2010.blogspot.com)*

specimens for both grades of concrete).The results of slump, V-Funnel and L-Box tests after satisfying the fresh properties of SCC as per EFNARC-2005 specifications as shown in Table-7, Table-8 and Table-9.

a. Slump Flow test

The slump flow test is used to assess the filling ability of SCC. The time for 500mm spread of concrete and diameter is measured in Unprocessed and Processed State and is shown in Table-7. The time for 500mm spread of concrete i.e., T_{50}values at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-1. The diameter spread of concrete at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-2.

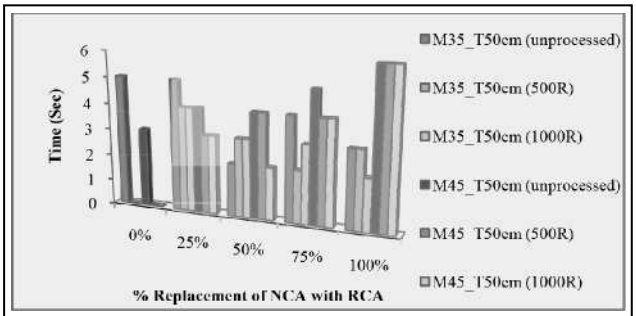


Fig. 1 T_{50} values of Slump flow test for various replacement levels of RCA

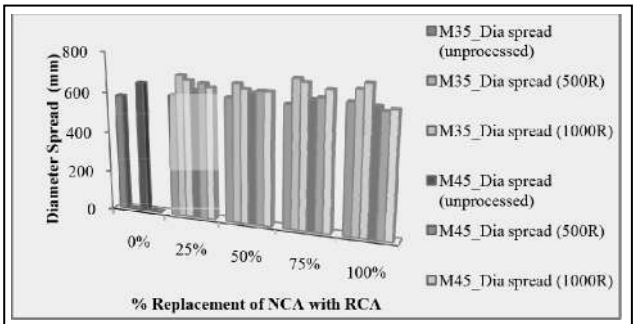


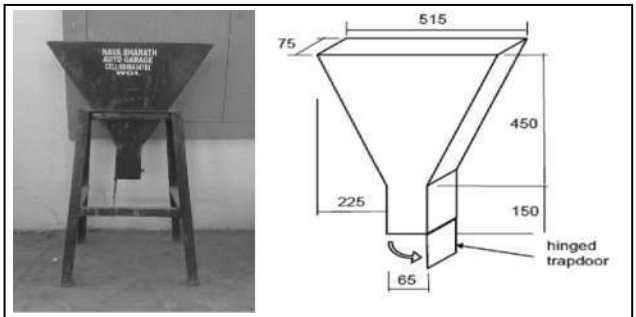
Fig. 2 Diameter of Slump flow test for various replacement levels of RCA

Table7 Results of Slump Flow Test in Unprocessed and Processed State

% of NCA replaced by RCA	M35 Grade of Concrete						M45 Grade of Concrete					
	Unprocessed State		*Processed State (500 R)*		*Processed State (1000 R)*		*Unprocessed State*		*Processed State (500 R)*		*Processed State (1000 R)*	
	T_{50} (sec)	*Slump Diameter (mm)*	*T_{50} (sec)*	*Slump Diameter (mm)*	*T_{50} (sec)*	*Slump Diameter (mm)*	*T_{50} (sec)*	*Slump Diameter (mm)*	*T_{50} (sec)*	*Slump Diameter (mm)*	*T_{50} (sec)*	*Slump Diameter (mm)*
0%	5	580	-	-	-	-	3	650	-	-	-	-
25%	5	600	4	700	4	680	4	635	3	670	3	650
50%	2	610	3	680	3	655	4	640	4	650	2	650
75%	4	600	2	720	3	705	5	630	4	640	4	680
100%	3	630	3	690	2	720	6	620	6	600	6	610

b. V-Funnel Test

The V-funnel test is used to assess the segregation resistance of the concrete. The T_{5min} time of SCC is measured in Unprocessed and Processed State and is shown in Table-8. The time after 5 minutes is measured in V-funnel test i.e., T_{5min} values at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-3.



V-funnel test equipment
(Courtesy from civil-online2010.blogspot.com)

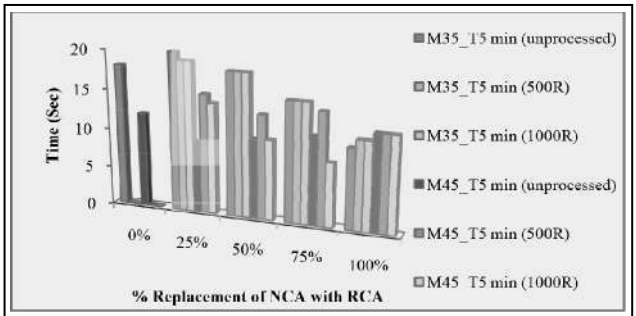


Fig. 3 T_{5min} values of V funnel test for various replacement levels of RCA

C. L-Box Test

This test is used to assess passing ability of SCC. The concrete is allowed to pass through the reinforcing bars and blocking ratio (H2/H1) is measured. The blocking ratio of SCC at various replacement levels of RCA in Unprocessed and Processed State is shown in Table-9.

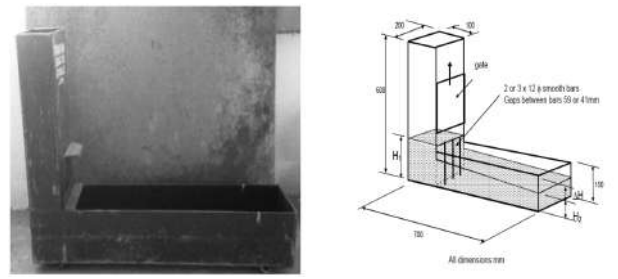


Fig.4 Blocking Ratio H2/H1 values of L Box test for various replacement levels of RCA

The blocking ratio of SCC at various replacement levels of RCA in Unprocessed and Processed State is shown by bar chart representation in figure-4.

Experimental Program

a. Compressive Strength Test

Self-compacting concrete with a similar water/cement or water/binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to the less vibrationsresults in an improved interface between the aggregate and hardened paste. The compressive strength of SCC at various replacement levels of RCA in Unprocessed and Processed State for 14

Compressive Strength test on cube specimen

Table 8 Results of V-Funnel Test in Unprocessed and Processed State

% of NCA replaced by RCA	M35 Grade of Concrete			M45 Grade of Concrete		
	Unprocessed State	*Processed State (500 R)*	*Processed State (1000 R)*	*Unprocessed State*	*Processed State (500 R)*	*Processed State (1000 R)*
	T_{5mins}	T_{5mins}	T_{5mins}	T_{5mins}	T_{5mins}	T_{5mins}
0%	18	-	-	12	-	-
25%	20	19	19	09	15	14
50%	18	18	18	10	13	10
75%	15	15	15	11	14	8
100%	10	11	11	12	12	12

Table 10 Compressive strength of cube specimens in unprocessed and processed state

% of NCA replaced by RCA	M35 Grade of Concrete						M45 Grade of Concrete					
	Unprocessed State		*Processed State (500 R)*		*Processed State (1000 R)*		*Unprocessed State*		*Processed State (500R)*		*Processed State (1000R)*	
	Compressive Strength (N/mm2)		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*	
	14 Days	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*
0%	31.35	36.07	-	-	-	-	40.03	53.43	-	-	-	-
25%	41.41	46.24	41.21	51.90	41.02	49.55	36.66	49.6	39.5	53.17	39.2	52.4
50%	42.68	50.86	43.41	52.61	42.79	51.32	41.46	53.61	42.6	54.47	42	53.8
75%	40.54	43.74	41.21	50.83	40.91	48.32	39.4	51.06	40.2	52.14	41.3	51.9
100%	32.55	36.91	38.35	45.18	37.61	44.90	38.6	50.51	38.3	50	40.6	50.8

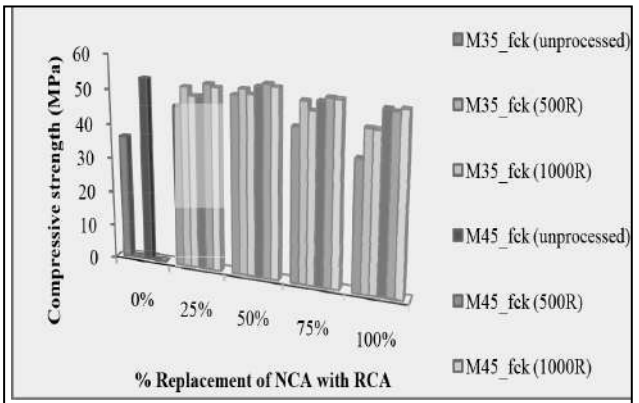


Fig. 5 Compressive strength of SCC at various replacement levels of RCA

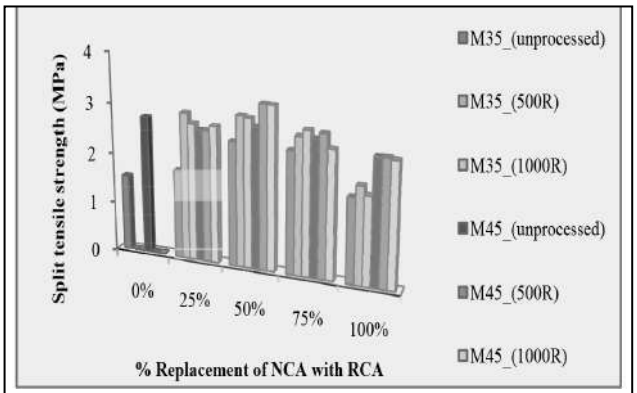


Fig. 6 Split tensile strength of SCC at various replacement levels of RCA

days and 28 days are shown in Table-10. The bar chart representation in figure-5 shows that there is an increase in compressive strength up to 50 percent replacement of RCA in Unprocessed and Processed State.

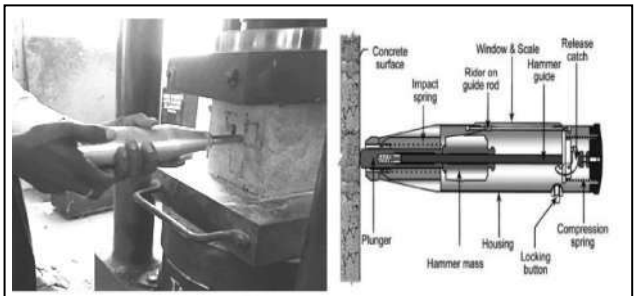
b. Split Tensile Strength Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on

Table 11 Split Tensile Strength test for cylinders in unprocessed state and processed state

% of NCA replaced by RCA	M35 Grade of Concrete						M45 Grade of Concrete					
	Unprocessed State		*Processed State (500 R)*		*Processed State (1000 R)*		*Unprocessed State*		*Processed State (500 R)*		*Processed State (1000 R)*	
	Split Tensile Strength (N/mm2)		*Split Tensile Strength (N/mm2)*		*Split Tensile Strength (N/mm2)*		*Split Tensile Strength (N/mm2)*		*Split Tensile Strength (N/mm2)*		*Split Tensile Strength (N/mm2)*	
	14 Days	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*
0%	1.47	1.52	-	-	-	-	1.4	2.75	-	-	-	-
25%	1.61	1.75	1.80	2.90	1.73	2.71	1.2	2.6	1.6	2.6	1.5	2.7
50%	2.12	2.44	2.40	2.95	2.40	2.92	1.42	2.77	2.2	3.21	2.12	3.2
75%	1.66	2.40	2.12	2.67	2.02	2.80	1.3	2.66	1.8	2.77	1.7	2.5
100%	1.42	1.66	1.61	1.89	1.51	1.72	1.01	2.45	1.7	2.45	1.8	2.42

concrete cylinder is a method to determine the tensile strength of concrete. Split tension test for normal conventional concrete is an established fact. The present experimentation using RCA under self compacting conditions will become an important parameter from tensile strength point of view. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members shows crack.



Rebound Hammer test on cube specimen

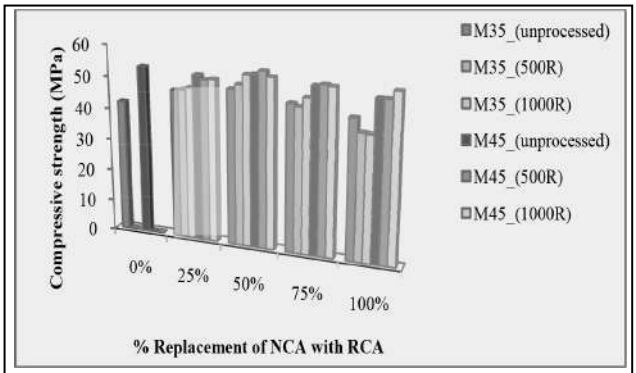


Fig.7 Compressive strength of SCC using Rebound hammer at various replacement levels of RCA

The Split Tensile Strength of SCC at various replacement levels of RCA in Unprocessed and Processed State for 14 days and 28 days are shown in Table-11. The bar chart representation in figure-6 shows that there is an increase in Split Tensile Strength up to 50 percent replacement of RCA in Unprocessed and Processed State.

c. Rebound Hammer Test

The Schmidt rebound hammer is principally a surface hardness test. It works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. There is little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. However, within limits, empirical correlations have been established between strength properties and the rebound number. The compressive strength using rebound hammer at various replacement levels of RCA in Unprocessed and Processed State for 14 days and 28 days are shown in Table-12. The bar chart representation in figure-7 shows that there is an increase in compressive strength using rebound hammer up to 50 percent replacement of RCA in Unprocessed and Processed State.

Results and Discussions

From the Figure 8, it is observed that the optimum compressive strength of cube specimens for 28 days is obtained at 50% replacement of RCA with NCA and later on there is a decrease in strength from 50% to 100% replacement of RCA with NCA in both unprocessed and processed states. For M35 grade of concrete the

Table 12 Rebound Hammer values for cubes in unprocessed and processed state

% of NCA replaced by RCA	M35 Grade of Concrete						M45 Grade of Concrete					
	Unprocessed State		*Processed State (500 R)*		*Processed State (1000 R)*		*Unprocessed State*		*Processed State (500 R)*		*Processed State (1000 R)*	
	Compressive Strength (N/mm2)		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*		*Compressive Strength (N/mm2)*	
	14 Days	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*	*14 Days*	*28 Days*
0%	36.28	41.86	-	-	-	-	39	53.3	-	-	-	-
25%	45.51	46.87	41.86	47.12	43.74	47.94	36	52	39	50.7	40.2	51
50%	46.87	48.61	43.74	50.10	43.74	53.17	40.3	53.5	42.1	54.6	42.2	53
75%	40.24	45.87	40.62	45.00	41.62	47. 86	38.1	51.5	41.2	52	41.8	51.6
100%	38.21	43.12	38.74	39.06	35.62	38.74	36	49.4	38.2	49.4	41.2	51.8

optimum strength in unprocessed state is 50.86 MPa, the optimum Strength in processed state i.e. for 500 revolutions is 52.61 MPa and the optimum Strength in processed state i.e. for 1000 revolutions is 51.32 MPa. For M45 grade of concrete the optimum strength in unprocessed state is 53.61 MPa, the optimum Strength in processed state i.e. for 500 revolutions is 54.47 MPa and the optimum Strength in processed state i.e. for 1000 revolutions is 53.80 MPa. Therefore with processing of RCA mechanical properties can be improved. This may be due to the densification of the internal structure and better interlocking of the aggregates.

By comparing the Strength results of Processed (1000 revolutions), Processed (500 revolutions) and Unprocessed state, it is observed that Processed recycled coarse aggregate (500 revolutions) obtained higher strength values than the Unprocessed recycled coarse aggregate and Processed recycled coarse aggregate (1000 revolutions). This is due to the removal of adhered cement motor present on the recycled coarse aggregate by abrasion which decreases the water absorption and increases the strength of concrete.

In the processed aggregate the removal of mortar from the external surface of the aggregate modifies the surface texture. This may be the reason for better flow ability in SCC with processed recycled coarse aggregate when compared with unprocessed recycled coarse aggregate.

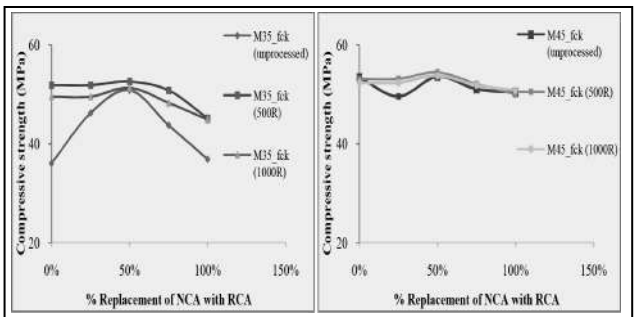


Fig. 8 Compressive strength of SCC at various replacement levels of RCA

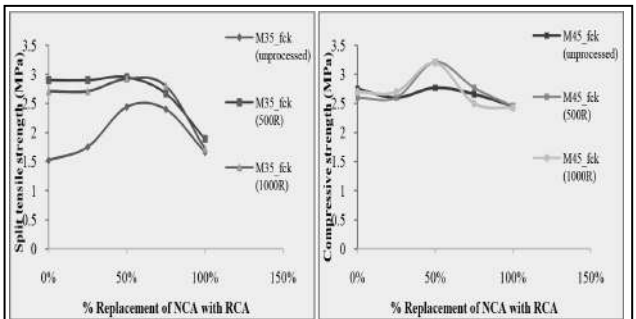


Fig.9 Split tensile strength of SCC at various replacement levels of RCA

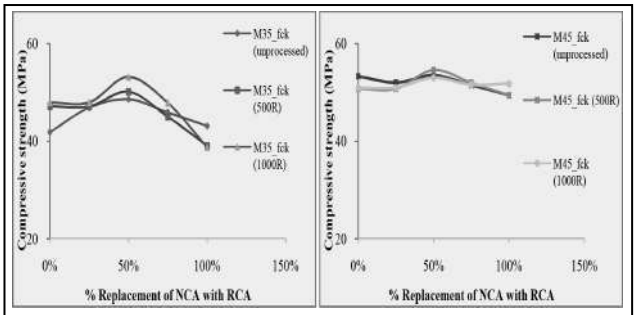


Fig.10 Compressive strength of SCC using Rebound Hammer at various replacement levels of RCA

From the Figure 9, it is observed that the optimum Split Tensile strength of cylinder specimens for 28 days is obtained at 50% of replacement of RCA with NCA in SCC and later on there is a decrease in Strength from 50% to 100% Replacement of RCA with NCA in both unprocessed and processed states.

For M35 grade of concrete the optimum Strength in Unprocessed state is 2.44 MPa, in processed state i.e., for 500 revolutions is 2.95 MPa and in processed state i.e., for 1000 revolutions is 2.92 MPa. For M45 grade of concrete the optimum Strength in Unprocessed state is 2.77 MPa, in processed state i.e., for 500 revolutions is 3.21 MPa and in processed state i.e., for 1000 revolutions is 3.20 MPa. Therefore with processing of RCA split tensile strength can be improved. Addition of flyash and rate of reaction may be the reason for improving in split tensile strength.

From the Figure 10, it is observed that the optimum compressive strength of cube specimens for 28 days using Rebound hammer is obtained at 50% of replacement of RCA with NCA in SCC and later on there is a decrease in Strength from 50% to 100% Replacement of RCA with NCA. For M35 grade of concrete the optimum Strength in Unprocessed state is 48.61 MPa ,in processed state i.e. for 500 revolutions is 50.10 MPa and in processed state i.e. for 1000 revolutions is 53.17 MPa. For M45 grade of concrete the optimum Strength in Unprocessed state is 53.50 MPa , in processed state i.e. for 500 revolutions is 54.60 MPa and in processed state i.e. for 1000 revolutions is 53.00 MPa.

Conclusions

1. The fresh properties of SCC in processed state for 500 revolutions have shown better results compared to unprocessed state with respect to self compacting.

2. For SCC using processed (500, 1000 revolutions) and unprocessed RCA the optimum value of Compressive strength, Split Tensile strength and Rebound Hammer value is obtained at 50% replacement of NCA with RCA for 14 days and 28 days.

3. In M35 and M45 grade of concrete 100% replacement of NCA by RCA without sacrificing the compressive strength and split tensile strength when compared with conventional SCC.

4. By processing of RCA upto 500 revolutions the compressive strength and split tensile strength can be improved.

5. The destructive and non destructive strengths showed better correlation in results in both unprocessed and processed state.

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Effect of Different Curing Methods on the Strength of Recycled Aggregate Self Compacting Concrete (RASCC)

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***Abstract*—Self-compacting concrete is high performance concrete that can flow under its own weight through restricted sections without segregation and bleeding.SCC is achieved by reducing the volume ratio of aggregate to cementetious material, increasing the paste volume and using viscosity enhancing admixtures and super plasticizers.Growing demands of effective construction waste management techniques to cater for the shortage of construction resources has compelled research on recycled aggregates in concrete. In this paper, the effect of different curing techniques on strength ofRecycled Aggregate Self Compacting Concrete(RASCC) is studied by using three different curing methods; normal water curing, site curing by sprinkling water and self-curing are the three methods employed. The variables of study include grade of concrete, percentage of Recycled Concrete Aggregate (RCA) and curing period (3, 7 and 28 days). Two grades of concrete M30 and M50 and five different percentages of RCA from 0 to 100% with an increment of 25% are used in this study. It is observed from the experimental results that site curing and membrane curing are giving strengths comparable to that of conventional water curing though there is a marginal reduction in the strengths.**

***Keywords*—Self-Compacting Concrete(SCC), Recycled aggregates, Field Curing, Membrane Curing, Compressive strength.**

I. INTRODUCTION

One of the major challenges of our present society is the protection of environment. Some of the important elements in this respect are the reduction of the consumption of energy and natural raw materials, and consumption of waste materials. These topics are getting considerable attention nowadays under sustainable development. The use of recycled aggregates from construction and demolition wastes is showing prospective application in construction as alternative to primary (natural) aggregates. It conserves natural resources and reduces the space required for the landfill disposal. The physical properties of recycled aggregates depend on both adhered mortar quantity and quality.

The adhered mortar is a porous material; its porosity depends upon the w/c ratio of the recycled concrete employed.Crushing C&D waste concrete to produce coarse aggregate for the production of new concrete is a common means for achieving an environment-friendly concrete. The crushing procedure and the dimension of the recycled aggregate influence the quantity of adhered mortar. The density and absorption capacity of recycled aggregates are affected by adhered mortar, and they must be known before utilization of recycled aggregates to control properties of fresh and hardened concrete.

The objective of this paper is to study the compressive strength of M30 and M50 grades of concrete using recycled aggregate self-compacted concrete with three different types of curing methods i.e. normal curing, site curing and self-curing.

II. LITERATURE REVIEW

Hajime okamura and Masahiro ouch [1] discussed about the properties of self-compacted concrete and tests that should be conducted in detailed manner. **Engelson.J.C** adopted NAN-SU method of mix design for his work and is based on packing factor (PF) of aggregate. PF is the ratio of mass of aggregate of tightly packed state in SCC to that of loosely packed state. And the workability tests performed in this research were as per **EFNARC [12]. Mohd Nadeem and SomnathGhosh[2]** presented the results of the effect of curing method on the strength development of alkali- activated blast cement paste. In this study, alkali activation was done using a combination of potassium hydroxide and sodium silicate. The test parameters include the curing methods (water curing at 27^{o}C, heat curing at 50^{o}C and controlled curing with relative humidity 50%, 70% and 90% at 27^{o} C), alkali content with 6.41%, 8.41%, 10.41% and 12.41% of the mass of GGBS.**Mohammed Shafeeque[3]** in their study, compared compressive strength and split tensile strength of concrete with curing agent with those of the conventionally curedself-compacting concrete.

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Nanak,et. al. [4, 8]carried out their investigations on variation in compressive strength of medium strength self-compacted concrete with 3 different curing techniques. **Nirav, et. al. [5]**made aneffort to understand the working and efficiency of curing methods which are generally adopted in the construction industry and compared with the conventional water curing method.**Nan Su, et.al. [6]** proposed a new mix design method for self-compacting concrete (SCC) and the results indicated that the proposed method could produce successfully SCC of high quality. Compared to the method developed by the Japanese Ready-Mixed Concrete Association (JRMCA), this method is simpler, easier for implementation, less time-consuming, requires a smaller amount of binders and saves cost.**Ratish Kumar [7]** addressed the effect of using paraffin wax as a self-curing compound in SCC mixes. The variable parameters of the study include curing type, concrete grade (mix proportions), molecular weight and dosage of paraffin wax. Water retention and compressive strength tests were conductedonhardenedconcretes.**R. K. Dhir, et. al. [9]**carried outan investigation into the feasibility of formulating 'self-cure' concrete. They are concerned with achieving optimum cure of concrete without the need for applying external curing methods. The feasibility of curing concrete by adding water-soluble chemicals during mixing that reduce water evaporation in the set concrete, making it 'self-curing' is discussed. The chemicals' abilities to reduce evaporation from solution and to improve water retention in ordinary Portland cement were monitored by measuring weight-loss.**R.J. Flatt, et.al.[10],** in his articles, discussed models that are being developed to achieve the task of self-curing. A treatment of interparticle forces and a yield stress model integrating these were presented. **S.W.Tabsh and A. S. Abdel Fatah, et. al. [11],** carried out the research on recycled aggregate.Los Angeles degradation test results indicate that the percentage loss of the recycled concrete aggregate is within the acceptable limit of 50% for structural applications, irrespective of its origin. The aggregate soundness test results, based on five cycles in saturated solution of sodium sulfate, show that the percentage loss of the recycledaggregates made from concrete withminimum strength of 30 MPa are within the acceptable limit.

Experimental Programme:

A. Materials:

Ordinary Portland cement:OPC of 43 grade, confirming to IS 8112:1989 and locally available river sand as fine aggregate (zone-II) confirming to IS-2386, are used in this work. The properties of fine aggregate & Calculation of Fine Aggregate Content for M 30 &M50 gradeNASCC and RASCC with Different proportion of RCAused are shown in Table 2.

Coarse Aggregate: The coarse aggregates used in the project are both recycled and natural aggregate. Recycled Coarse Aggregate (RCA) is obtained from the waste concrete brought from the Demolished Building structure in Hyderabad, Telangana, India. Natural aggregate is replaced by recycled coarse aggregate in four different proportions, i.e., 25%,50%,75% and 100%. The maximum size of the aggregate was taken as 12.5mm.The Calculation of Coarse Aggregate Content for M30 and M50 grade NASCC and RASCC with different proportion of RCA used are shown in Table 1.

*Mix Design:*The mix design is based on the proposed Modified Nan Su Mix design analysis.Quantities of different ingredients of M30 and M50 Grade NASCC and RASCCare shown in Table 3.

Mixing: Two stage mixing approach (TSMA)is employed for this research work. In normal mixing method, all the ingredients are fed sequentially and mixed in one go. For further improvement in the properties of concrete with recycled concrete aggregate, two-stage mixing has been advocated. In the two-stage mixing method, all the materials including processed recycled aggregate (except virgin recycled aggregate) were loaded in the pan mixer in the first stage and then the virgin coarse aggregate, which need not require any treatment, was added in the second stage of mixing to complete the process. The total mixing time was 180 seconds in normal mixing and 300 seconds in two-stage mixing.

As per EFNARC guidelines Slump flow test, V-funnel test, and L-box test were carried out to determine the properties of SCCin fresh state. Compressive strength at the ages of 3, 7, and28 days was also determined. The properties of SCCmixes as obtained in M30 and M50 grade mixes are shown in Table No.4.

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B. Mix Design:

TABLE NO 1
CALCULATION OF COARSE AGGREGATE CONTENT FOR M 30 &M50 GRADE NASCC& RASCC WITH DIFFERENT PROPORTIONS OF RCA

MIX	% RCA	Specific gravity	Packing factor	Bulk density in kg/m^3	Prop. coarse aggregate	Quantity of coarse aggregate in kg/m3
M30	0	2.65	1.12	1380	0.48	741.88
	25	2.6	1.12	1373	0.48	738.12
	50	2.53	1.13	1365	0.48	740.376
	75	2.48	1.13	1360	0.48	737.664
	100	2.45	1.14	1355	0.48	741.456
M50	0%	2.65	1.12	1380	0.48	741.88
	25%	2.6	1.12	1373	0.48	738.12
	50%	2.53	1.13	1365	0.48	740.376
	75%	2.48	1.13	1360	0.48	737.664
	100%	2.45	1.14	1355	0.48	741.456

TABLE NO (2):
CALCULATION OF FINE AGGREGATE CONTENT FOR M 30 &M50 GRADENASCC& RASCC WITH DIFFERENT PROPORTIONS OF RCA

Mix	Packing factor	Bulk density In kg\m^3	Specific gravity	Proportion of fine aggregate	Quantity in kg/m^3
M30	1.12	1347	2.45	0.52	784.492
M50	1.12	1347	2.45	0.52	784.492

TABLE NO (3):
QUANTITIES OF DIFFERENT INGREDIENTS OF M30 AND M50 GRADE NASCC& RASCC

Mix	% of RCA	Coarse Aggregate	FineAggregate	Cement	Fly ash	Water	Super plasticizer	VMA
		Qty in kg/m^3						
M30	0	741	784	416	125	187	6.7	0.67
	25	741	784	416	125	189	6.7	0.67
	50	741	784	416	125	191	6.7	0.67
	75	741	784	416	125	193	6.7	0.67
	100	741	784	416	125	195	6.7	0.67
M50	0	741	784	506	50	192.4	8.211	0.82
	25	741	784	506	50	194.4	8.211	0.82
	50	741	784	506	50	196.4	8.211	0.82
	75	741	784	506	50	198.4	8.211	0.82
	100	741	784	506	50	200.0	8.211	0.82

TABLE NO (4):
FRESH PROPERTIES OF M30&M50 GRADE NASCC& RASCC WITH DIFFERENT PROPORTIONS OF RCA

MIX	% RCA	Slump Cone Test in mm	T50 Slump Flow Results in sec	V-Funnel Test Results in sec	L- Box Test (h_2/h_1) Test Results
M30	0%	737	3	8	0.8
	25%	735	3	8	0.8
	50%	720	3	8	0.8
	75%	700	3	9	0.8
	100%	670	4	9	0.8
M50	0%	745	3	7	0.8
	25%	720	3	8	0.8
	50%	720	3	8	0.8
	75%	700	3	9	0.8
	100%	680	3	9	0.8

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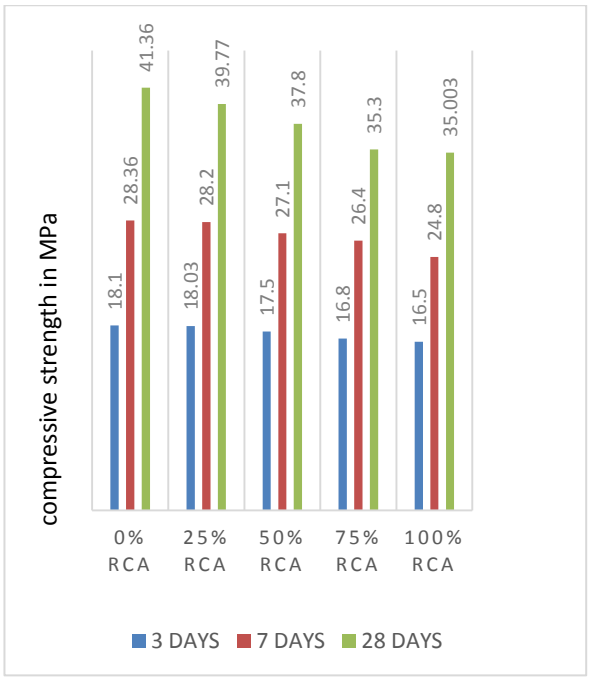

Fig:(1) Variation of compressive strengths for different RCA content and ages for M30 Concrete- normal curing.

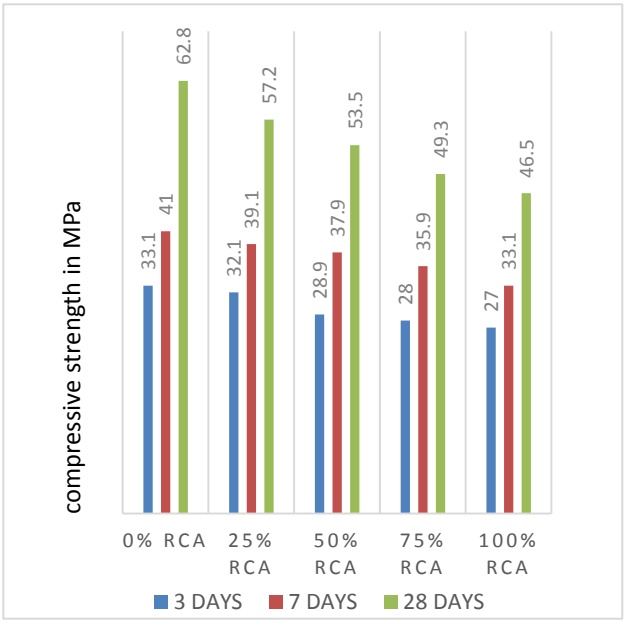

Fig:2 Variation of compressive strengths for different RCA content and ages for M50 Concrete- normal curing.

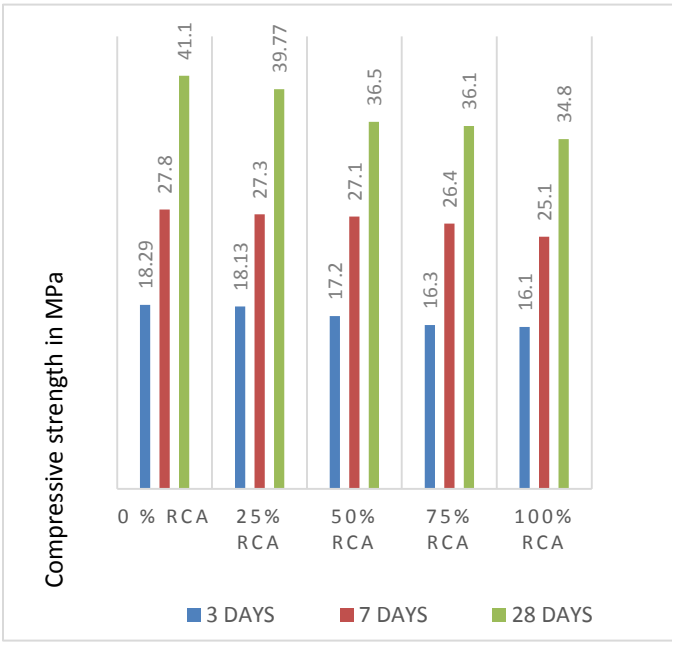

Fig:3Variation of compressive strengths for different RCA content and ages for M30 Concrete- site curing,

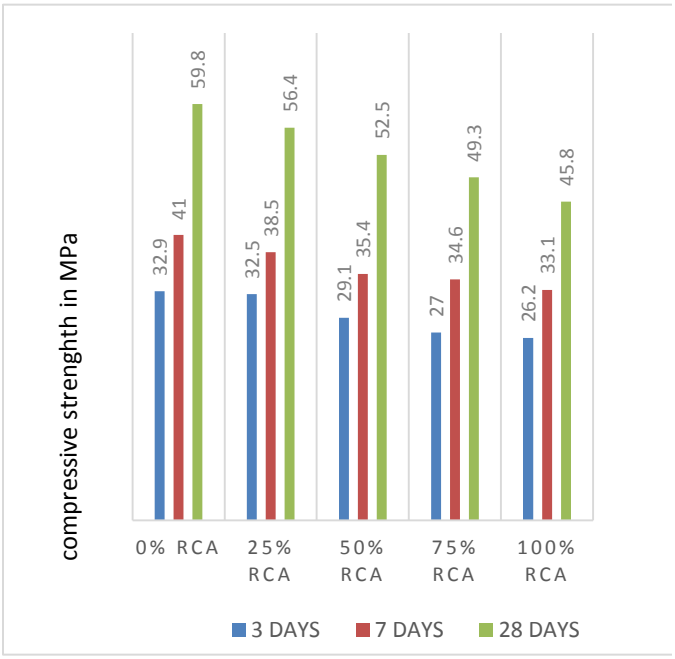

Fig:4 Variation of compressive strengths for different RCA content and ages for M50 Concrete- site-curing

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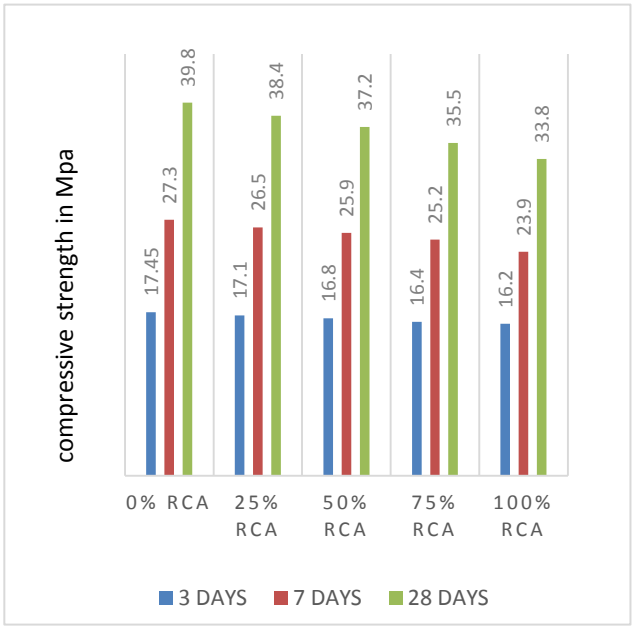

Fig:(5)- Variation of compressive strengths for different RCA content and ages for M30Concrete- self-curing

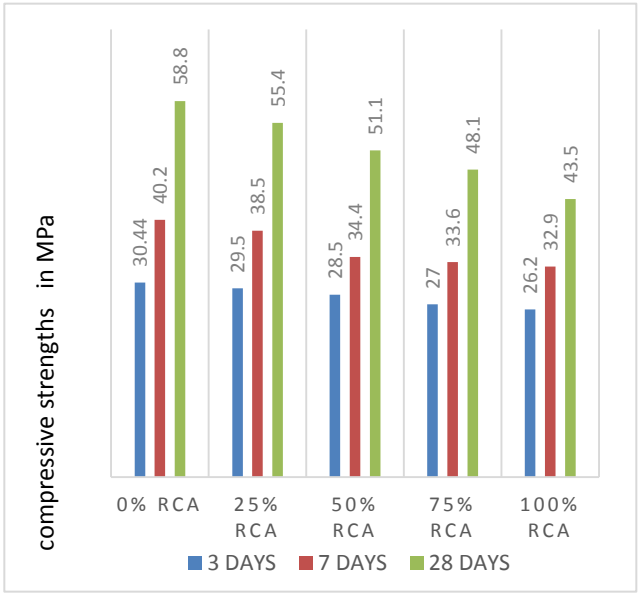

Fig: (6)- Variation of compressive strengths for different RCA content and ages for M50 Concrete-self-curing

III. Discussion On Test Results

1. Workability Properties Of M30&M50 Grade Concrete

*a) Slump cone test results for M30&M50*The natural aggregate has slump flow of 737 mm for M30 grade concrete. The slump value is found to decrease as percentage of RCA increased in the mix. The minimum slump obtained for 100% RCA is 670 mm. Similar trend was observed in M50 grade concrete also. The slump values ranged between 745 mm and 680mm for M50 grade.

b) T-50 Slump Flow Results: The natural aggregate has T 50 slump value as 3 sec and there is no change in the value of T-50 slump flow for all replacements of aggregate for M30&M50 grade of concretes

c) V-Funnel Test Results: The natural aggregate concrete has V-funnel value of 8 sec and the same value is maintained even for 25%,50% and 75% replacement ofRCA. V-funnel time increased marginally to 9 seconds for 100% replacement. There is not much change observed in V- funnel test results of M50 concrete also. The natural aggregate mix has V-funnel value of 7 sec and for 25 % replacement of natural aggregate and for 50% replacement the value was 8 sec and for 75% and 100% replacement, v-funnel value was 9sec.

*d) L-Box test results:*There was no change in L-Box test results for M30andM50 mix it had same value of 0.8 for all replacementsfor M30 and M50 grades of concretes

2. Compressive Strength Of M30&M50 Grade Concretes By Normal Curing, Site Curing And Self Curing

*Compressive strength of conventionally cured concrete:*The Variation of compressive strengths for different RCA content with normal cured concrete was determined at the ages of 3, 7 and 28 days for M30and M50are shown in Fig.1 and Fig.2 respectively. The compressive strengths of both M30&M50 Grade concretes is observed to decrease with increased recycled aggregate content at all ages. The reduction in compressive strength of M30 grade concrete is less than 10% for 3 days curing while it is about 15% for 28 days curing. However, for M50 grade concrete, the maximum reduction in strength due to the inclusion of RCA is around 20% for both 3 days and 7 days curing while it is about 25% for 28 days curing. This clearly shows that the loss of compressive strength is more in higher grade concretes. The Target strength is reached for M30 grade concrete up to 50% replacement natural aggregate by RCA and beyond 50% replacement there is marginal deviation from the target strength.

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However, for M50 grade concrete the target strength could reach only for natural aggregate concrete. As the deviation of target strength negligibly small, 25% RCA is recommended asreplacement of natural aggregate for M50 grade concrete.

Effect of Site Curing on compressive strength: The Results of site curing also followed the similar trend as that of normal curing.The Variation of compressive strengths for different RCA content with site curing concrete was determined at the ages of 3, 7 and 28 days for M30and M50 concretes and are shown in Fig.3. and Fig.4 respectively. The strengths observed in site curing are almost same as those obtained for normal curing for M30 grade concrete at all ages of testing. However, there is a marginal decrease observed in M50 grade concrete. The Target strength is reached for M30 grade concrete up to 75% replacement of natural aggregate by RCA and beyond 75% replacement there is marginal deviation from the target strength. However, for M50 grade concrete the target strength could reach only for natural aggregate concrete. As the deviation of target strength is negligibly small, 25% RCA is recommended for M50 grade concrete as replacement of natural aggregate.

*Effect of Self Curing on compressive strength:*The Variation of compressive strengths for different RCA content withSelf curing concrete was determined at the age of 3, 7 and 28 days for M30and are shown in Fig.5. The same for M50are shown in Fig.6. Results of self-curing concrete strengths observed are almost same as those obtained for normal and site curing for M30 grade concrete at all ages. However, there is a marginal decreaseinM50gradeself-curing recycled aggregate self-compacting concrete.

IV. CONCLUSIONS

This study investigated the behaviour of NASCC and RASCC at different curing methods. Specimens of M30 and M50 Grade Concretes were made and subjected to different curing methods viz conventional curing, site curing and self-curing. The following conclusions are drawn based on the experimental investigations carried out:

- The fresh properties requirements of SCC are met with for all the mixes tested, i.e., both the grades M30&M50 and all the RCA contents from 0% to 100% as replacement of natural aggregate.
- The slump spread value reduced with the increase of RCA content in both the concretes. However, the slump spread value is more for M50 concrete compared to M30 grade.
- The target strengths are reached, while meeting fresh properties, for Self compacting recycled aggregate concrete of both the grades when 50% natural aggregate is replaced by RCA.
- There is not much change in the compressive strengths of NASCC & RASCC of M30&M50 grade at 3 and 7 days age, for 50% replacement of natural aggregate by RCA. However, the loss of strength of around 14% is observed for RCA 75% and 100% at the ages of 28 days.
- There is marginal decrease in compressive strengths of M30 and M50 concretes at all ages and for all RCA Contents when the curing method changed from conventional to site curing or membrane curing.
- From this study it is concluded that self-curing techniques can be adopted, without compromising the strength, at places where there is acute shortage of water.
- Utilization of Recycled concrete aggregate as natural aggregate replacement avoids the environmental and ecological damages caused by quarrying and exploitation of raw materials like Coarse aggregate for making concrete. Substitution of RCA will help to conserve the valuable natural resources.

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