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Development of an Empirical Co-Relationship between Dynamic Cone Penetrometer (DCP) and Maximum Dry Density (γ_{max}) of Different Soils

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Abstract. **In this research a portable in-situ device known as Dynamic Cone Penetrometer (DCP) is utilized in order to develop co-relations between DCP - Max: dry density and DCP - Optimum moisture content (OMC) on different soil samples. These soil samples have been prepared by firstly using pure clayey soil and replacing the proportion of clay content with sand content. Different soil samples prepared were belonging to different soil groups which are estimated by calculating its plasticity index from fall cone method. From this research it is evaluated that DCP results can be utilized to estimate Max: dry density and OMC of different soils with confidence.**

Keywords: Dynamic cone Penetrometer (DCP), Maximum Dry Density (γ_{max}), Optimum Moisture Content (OMC)

I. INTRODUCTION

DCP developed in 1950 is least expensive, simple, portable but effective means of determining in situ soil properties without digging test pits overcoming laboratory sampling. [1] Determination of different tests like CBR requires need of equipment and much time to conduct the test. Alternatively different other tests may be used to predict CBR value of sub grade by developing a co-relation between CBR and DCP.[7]Dynamic penetration test is one of the oldest, cost efficient in situ tests in the field of geotechnical engineering which is used to evaluate the soil characteristics and to design engineering work. Different researches have been done to develop relationship between dynamic penetration and different properties of soil and different dynamic penetrometers. [5] Experimental study on various soil to correlate DCP with PBT, UCS and CBR results is discussed [10]DCP, stiffness, shear strength and R-value have developed a good relationship which can be used in the field to evaluate soil parameters.[12].Relationship between DCP and soaked CBR value is developed with determination (R) of 0.89 and relation between DCP and dry density was also originated.[6] CBR is predicted from different other test like DCP (DCP) and soil properties in a valuable alternative as CBR can't be measured easily in the field. The quantification of un-soaked CBR and DCP of various soils are enabled by using laboratory and field equipments following the various soil compactions at different initial state conditions (i.e. water content and dry density). After different research it was concluded that a good relationship between un-soaked CBR and DCP can be developed with the soil initial state factor as described by the merging of initial dry density, water content and void ratio. The comparison of measured and predicted values of un-soaked CBR and DCP was done to verify the relationship. [2]

By reviewing different researches about DCP and relationship developed between DCP and different soil parameters, this study aims on developing a co-relation between DCP and proctor test results on different soils. Different soils are prepared by mixing clay with 0%,10%,20%,30%,40%,50%,60%,70%,80% and 90% sand. Soil varying from clayey soil to sandy soil is tested for its P.I. The modified proctor test is conducted and OMC and γ_{max} is evaluate on basis of these results DCP test is conducted. The relationship between OMC and DCP and γ_{max} and DCP is developed and verified.

II. MATERIALS AND METHODS

1. CLAY

Clay is natural geotechnical material which consists of few particles of clay minerals with a few metal oxides and organic metal. Clay is in the form of very fine natural particles. Presence of water content makes the clay plastic and it becomes hard, brittle and non-plastics when dried on fingers. The pictorial view of clay can be seen in Fig. 1.

Fig. 1: Clayey Soil Sample

2. *SAND*

Sand is a natural geotechnical material which consists of finely divided rocks and mineral particles. Its size is always between Silt and gravel i-e silt< sand<gravel. The pictorial view of clay can be seen in Fig. 2.

Fig. 2: Sandy Soil Sample

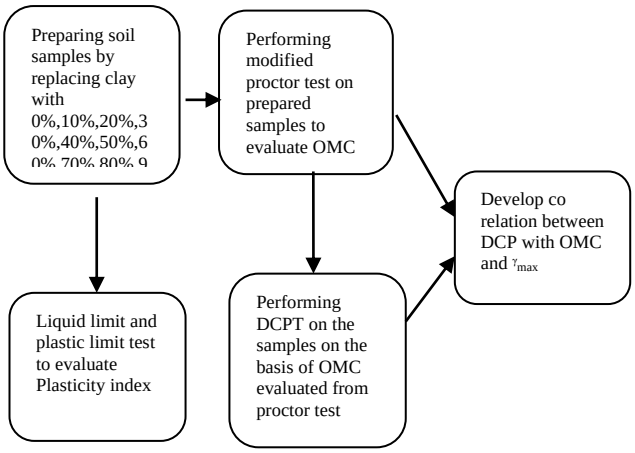
Table 1: Different soil samples by replacing clay with sand

SAMLPLES	CLAY (%)	SAND (%)
Sample no 1	100	0
Sample no 2	90	10
Sample no 3	80	20
Sample no 4	70	30
Sample no 5	60	40
Sample no 6	50	50
Sample no 7	40	60
Sample no 8	30	70
Sample no 9	20	80
Sample no 10	10	90

These prepared soil samples belonging to different soil groups are used in this research.

III. METHODOLOGY

Platicity index (P.I) is determined to evaluate soil. The OMC and $\boldsymbol{\gamma_{max}}$ from modified proctor test are evaluated. The cone penetration from DCP test is analyzed. A relationship is developed between γ_{max} and DCP and a relationship between OMC and DCP is also formulated.



Flow chart showing methodology

A. Plasticity Index

Plasticity Index can be evaluated by the difference of Liquid Limit and Plastic Limit (L.L, P.L). L.L was estimated by Fall Cone method and P.L was determined by calculating the moisture content of a soil when remolded and rolled between tips of finger and glass plate till the cracks appear on the sample which is rolled at diameter of 3mm as can be seen in Fig. 3.

Fig. 3: Liquid and Plastic limit test

Table 2: Atterberg's limits and soil group

SAMPLES	LIQUID LIMIT (%) (L.L)	PLASTIC LIMIT (%) (P.L)	PLASTICITY INDEX (%) (L.L-P.L)	SOIL GROUP
Sample no:1	57	30.5	26.5	A-7
Sample no:2	49	27	22	A-7
Sample no:3	39	18.7	20.3	A-6
Sample no:4	36	17.1	19	A-6
Sample no:5	32	16	15.98	A-6
Sample no:6	28	15.2	12.8	A-6
Sample no:7	26	14.89	11.75	A-6
Sample no:8	24.25	12.5	11.1	A-6
Sample no:9	21.5	11.8	9.7	A-4
Sample no:10	18	10.26	7.74	A-4

Results clearly states that as the sand content in the sample increased the L.L and P.L decreased which was ultimately decreasing P.I and soil was becoming stiffer and stiffer, as can be seen in Fig. 4.

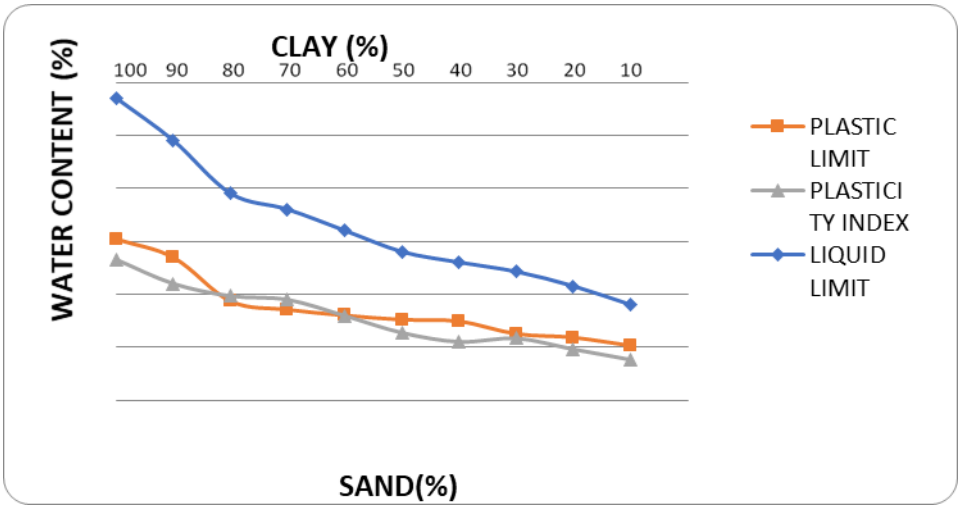


Fig. 4: Plastic limit, liquid limit and plasticity index

B. Modified Proctor Test

Maximum dry density can be achieved for the OMC which is determined by a laboratory method modified proctor test which can be seen in Figs. 5 & 6. Test was conducted on all 10 samples and it was evaluated that with increase of sand content OMC is decreasing and maximum dry density is increasing which proves the stiffness of soil.

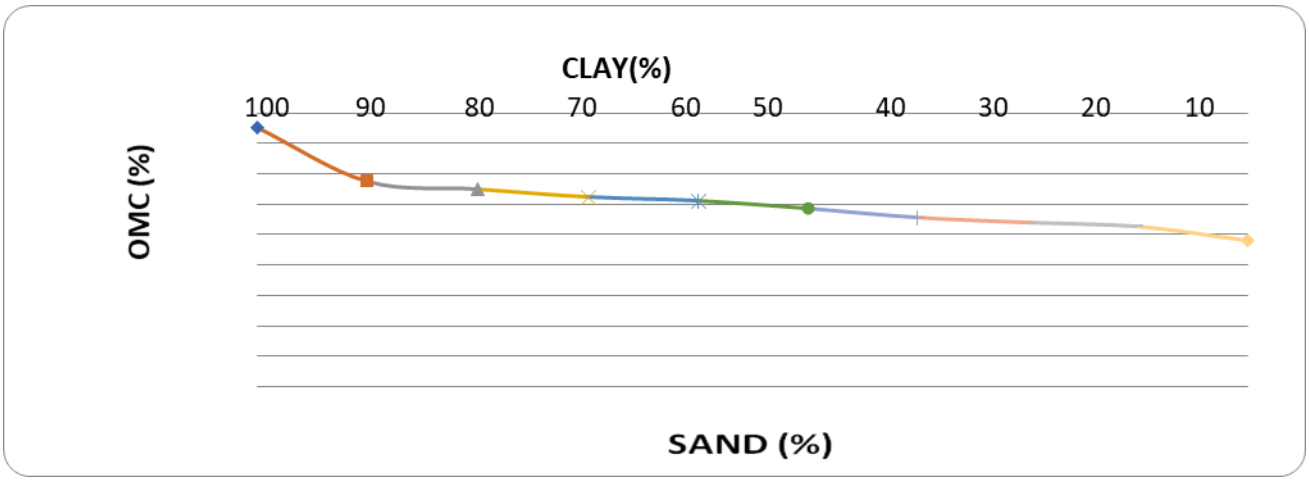


Fig. 5: OMC by modified proctor test

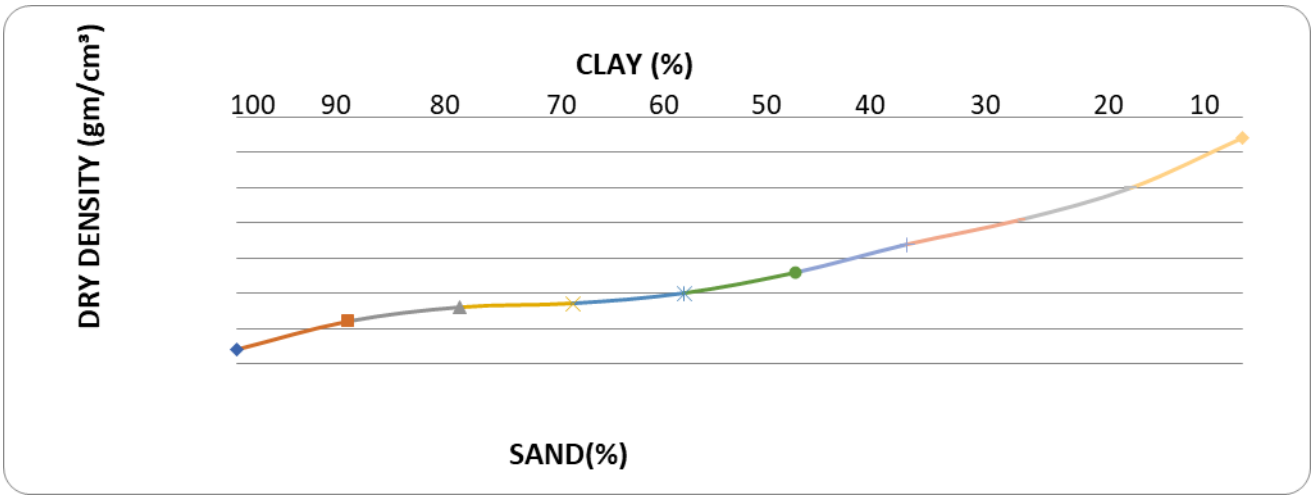


Fig. 6: γ_{max} by modified proctor test

It's estimated from modified proctor test results that by increasing Sand content soil is becoming near to non- plastic as sand is non- plastic material.

C. DCP TEST (DCPT)

DCP is cost efficient portable, rapid and in-situ strength evaluation device, as can be seen in Fig. 7.

Fig. 7: Dynamic Cone Penetrometer Test (DCPT)

The DCPT was conducted on the samples of maximum dry density and OMC obtained from modified proctor test which arrayed that penetration of the cone of DCP decreased as soil becomes strong with increase of sand, as can be seen in Table 3. The illustration of the DCPT results can also be seen in Fig.8.

Table 3: DCPT results

SAMPLE 1	INTIAL HEIGHT (cm) 2	HEIGHT /BLOW (cm) 3	CONE PENETRATION (cm) 4=(2-3)	γ_{max} (gm/cm^3)	OMC (%)
sample 1	97	84.5	12.5	2.199	16.8
sample 2	97	85.2	11.8	2.16	13.5
sample 3	98.5	87.4	11.1	2.178	13
sample 4	99	89	10	2.19	12.5
sample 5	99	90.5	8.5	2.2	12.3
sample 6	100	92	8	2.23	11.7
sample 7	103	95.5	7.5	2.26	11.3
sample 8	105	97.8	7.2	2.3	10.9
sample 9	105	99.2	5.8	2.37	10.6
sample 10	105	102	3	2.42	9.8

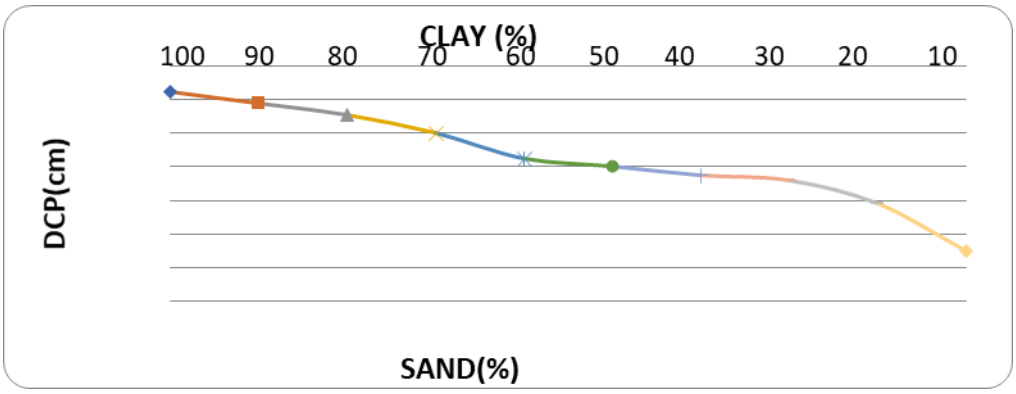


Fig. 8: DCP values

IV. RESULTS

1.Variation of OMC with DCP developing a relationship between DCP & OMC

Results confirm that approximate OMC can be obtained by performing DCPT on site. Thus, a co-relation between DCP value and OMC has been developed on the co-efficient of determination $R^2 = 0.968$, as can be seen in Fig. 9.

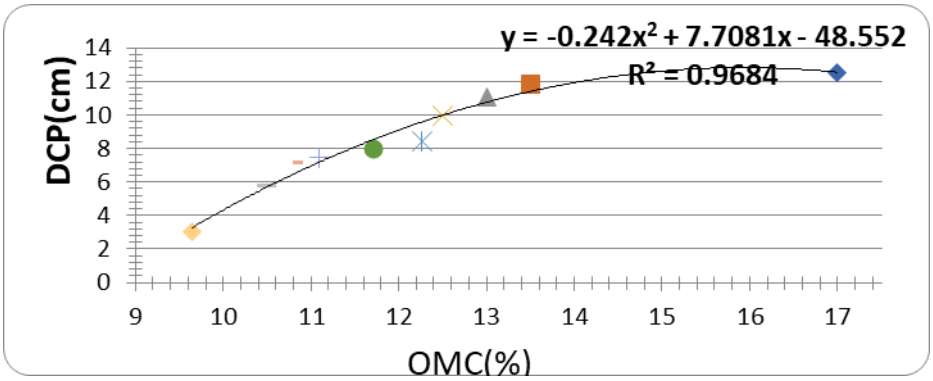


Fig. 9: Development of co relation between DCP and OMC

$$Y = -0.242x^2 + 7.708x - 48.55 \ldots\ldots\ldots (1)$$

Where,
Y= the value of DCP in cm
x= OMC in %

2. Variation of γ_{max} with DCP developing a relationship between DCP (cm) and γ_{max} (gm/cm^3)

The DCP value decreases with the increase of γ_{max}. The significant relationship between them is developed with the co-efficient of determination R^2=0.945 which will directly evaluate the max dry density of proposed site by performing DCPT on site, as can be seen in Fig. 10.

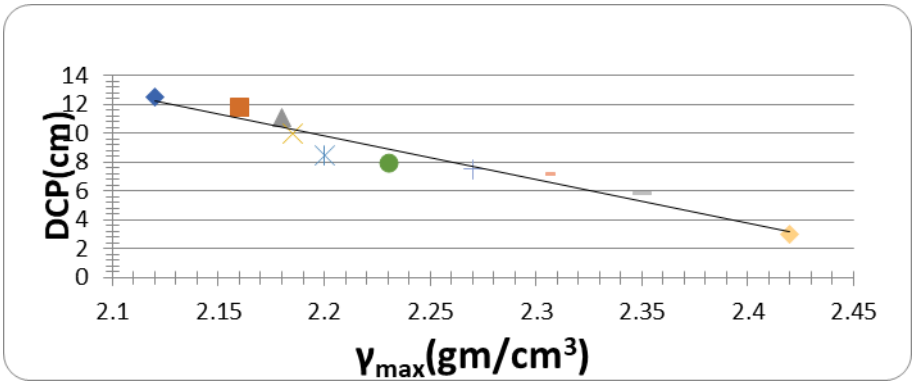


Fig. 10: Relationship between DCP and γ_{max}

The equation is

$$Y=19.83x^2-120.2x+178.3\ldots\ldots(2)$$

Where
Y= the value of DCP in cm
x= maximum dry density in (gm/cm^3)

From eq: 1 & 2 we can find max dry density and OMC by performing in-situ DCPT as its difficult to conduct modified proctor test directly on sites thus through this equation we have only to perform DCPT on site which is portable and easy to conduct and evaluate OMC and γ_{max} directly on site. The validation of above equations has been proved by comparing the OMC and γ_{max} determined after DCPT with OMC and γ_{max} determined during modified proctor test.

V. CONCLUSION

This study concludes the following results:
Plasticity index

- The results show that the P.I decreases with the increase of sand content in clayey soil.

Modified Proctor Test

- Maximum dry density increases & OMC decrease with decrease in P.I

Dynamic Cone penetration Test

- DCP has direct relation with OMC, increasing value of OMC increase DCP value.
- DCP has inverse relation with γ_{max}. DCP decreasing value will increase the value of max: dry density.
- Thus, DCP value decreases with increase of sand content as soil becoming near to non-plastic soil.
- Developed co-relation between DCP and γ_{max}

  $Y=19.83x^2-120.2x+178.$

Where Y represents DCP and x represents γ_{max}

- Developed co-relation between DCP and OMC

  $Y=-0.242x^2+7.708x-48.55$

Where Y represents DCP and x represents OMC

VI. RECOMMENDATIONS

- Soil is natural material thus while performing any test on any type of soil care should be taken.
- The relationship developed is only for clayey type soil and for type of soil which belong to soil group mentioned in this research.

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b. *R-value*".

Asphalt Mix Design for Base Course Using Fly Ash as a 100% Replacement of Mineral Filler

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***Abstract*: Asphalt mix design for base course using fly ash as a 100% replacement of mineral filler based on Marshal Stability method. Sample of Aggregate collected from hot bins from Asphalt crushing plant near Jamshoro and Fly ash collected from Lakhra coal power plant. The tests were conducted in the Highway Research laboratory of MUET. Many trials (by trial and error method for blending of aggregate) have been computed in order to achieve the desired grading and number of Marshal moulds (by Marshal stability method) have been prepared at various percentage of bitumen for optimum bitumen content. Finding of this research project have depicted the foundation of our construction industry and need to emphasis to use fly ash material in pavement construction and avoid the consequence of environmental.**

***Keywords*: Aggregate, Asphalt, Fly ash, Marshal stability.**

I. INTRODUCTION

Whatever the technique and precision is being made in design by designer, if the material which is being used in the construction is not as per requirement of design then this design will not give us our desire results and targeted life of structure. Therefore, for long life of structure either we have to use the material as per design specification or we have to make the design keeping in view the properties of local available materials. The design of asphalt paving mix , as with other engineering materials designs is largely a matter of selecting and proportioning materials to obtain the desired properties in the finished construction .By the use of fly ash in asphalt mix, Paving bricks backfill etc benefits occur when consider fly ash in construction industry. It prevents human plant life. While using fly ash in construction there is no need to dump waste material as landfills. Power plant of Lakhra is very closed to Jamshoro and Lakhra power plant is only operated power plant of Pakistan. The Lakhra have largest Coal field consist large area of 250sq km. Experts believe that there is about 500 million tons deposit of Lakhra coal for twenty-five years, coal is being taken from Lakhra coal mine quarry. Fly ash had been dumped in large area of power plant and its surrounding is polluted. Lot through gusts and gales blow during day and night. Also, coal mining dig and transport creates environmental problem to nearest villages. This alarm researcher to consume this landfill which has great sentimental impact in the surrounding society and on agriculture fields.

II. AGGREGATE ITS PROPERTIES AND TEST

The amount of mineral aggregate in asphalt paving mixture is generally 90-95% by weight and 75-85% by volume. Mineral aggregate is primarily responsible for load supporting capacity of pavement; accordingly asphalt paving is heavily influenced by aggregate. Aggregate has been defined as any hard-inert mineral material used for mixing in graduated particles or fragments. It includes sand, gravel, crushed, slag, rock dust or powder.

TABLE 1: PROPERTIES OF AGGREGATES

Property	Definition
Toughness	To resist fracture under impact
Strength	To resist heavy compressive load
Hardness	To resist wearing or abrasive action
Soundness or Durability	To resist weathering action
Shape and size	Property which show Flakiness and Elongation of aggregate particles
Adhesion with bitumen	Property which show binding of aggregate with bitumen
Porosity	Property which qualifies strength of aggregate by water absorption
Specific Gravity	Property which measures quality of aggregate, stronger or weaker

TABLE 2: SPECIFICATION FOR AGGREGATE GRADING FOR ASPHALT BASE COURSE FOR CLASS B

US Standard sieve size	%Passing by weight
1-1/2"(38mm)	100
1" (25mm)	75-90
¾ " (19mm)	65-80
½"(12.5mm)	55-70
3/8" (9.5mm)	45-60
No.4 (4.75mm)	30-45
No.8 (2.38mm)	15-35
No.50 (0.300mm)	5-15
No.200(0.075mm)	2-7

A. Quality Tests for Aggregate Gradation

Aggregate gradation is the distribution of particle sizes expressed as percent of the total weight. Gradation is determined by passing the material through a series of sieve stacked with progressively smaller openings, and weighing the material retained on each sieve.

TABLE 3: GRADATION OF COURSE AND FINE AGGREGATE AASHTO T-72 AND AASHTO C-136

US Standard sieve size	% Passing bin 01	% Passing bin 02	% Passing bin 03	%Passing bin 04
1-1/2"(38mm)	100	100	100	100
1" (25mm)	58.65	95.14	100	100
¾ " (19mm)	44.41	59.45	100	100
½"(12.5mm)	33.21	29.68	100	100
3/8" (9.5mm)	18.12	8.16	90.51	100
No.4 (4.75mm)	-	-	61.32	54.04
No.8 (2.38mm)	-	-	20.27	4.9
No.50 (0.300mm)	-	-	6.62	0.63
No.200(0.075mm)	-	-	3.41	-

B. Specific Gravity and Water Absorption Coarse and Fine Aggregate Test Results (AASHTO T-85 and AASHTO-84)

Specific gravity of an aggregate is the ratio of the weight of unit volume of material to the weight of same volume of water at 20-25 centigrade. Water absorption gives an idea of strength of rock. It is accepted as a measure of its aggregate porosity and sometime this value is even considered as a moisture of its resistance to frost action though this has not yet been confirmed by adequate research. Stone having more water absorption are generally considered unsuitable unless they are found to be acceptable based on strength impact and hardness tests.

TABLE 4: AVERAGE SPECIFIC GRAVITY AND WATER ABSORPTION OF COARSE AGGREGATE

Sieve Size	1-1/2"	1"	¾"	½"
Bulk Specific gravity (Oven dry)	2.7	2.67	2.67	2.75
Bulk Specific gravity (SSD)	2.75	2.70	2.72	2.85
Bulk Specific gravity (Apparent)	2.71	2.69	2.71	2.84
Water Absorption %	0.58	0.67	0.52	1.15

TABLE 5: AVERAGE SPECIFIC GRAVITY AND WATER ABSORPTION OF FINE AGGREGATE SIEVE SIZE #4

Name of test	Result
Bulk Specific gravity (Oven dry)	2.63
Bulk Specific gravity (SSD)	2.67
Bulk Specific gravity (Apparent)	2.79
Water Absorption %	2.55

C. Abrasion Test AASHTO T-96

Due to the movement of traffic the road stones used in the surfacing course are subjected to wearing action at the top. When fast moving vehicles with rubber tires moves on the road and steel types of animal drawn vehicles rub they cause abrasion of stones on the road surface.

TABLE 6: LOSS ANGELES ABRASION TEST

Name of test	Result
Percentage wear of material of grading A	25.2%
Percentage wear of material of grading B	27.3%
Percentage wear of material of grading C	27.5%
Percentage wear of material of grading D	31.8%

D. Soundness Test

This test is intended to study the resistance of aggregate to weathering action. In order to quicken the effect weathering due to the alternate wet dry and or freeze thaw cycles in the laboratory, the resistance to disintegration of aggregate is determine by soaking the aggregate specimen in saturated solution of sodium sulphate or magnesium sulphate. In this research we found the result of Soundness value is equal to 8.6%.

E. Stripping Value of Road aggregate Test

Bitumen and tar adhere well to all normal types of aggregates provided that they are dry and not exceptionally dusty. If a pavement is to be strong and durable the binder must adhere firmly to the aggregate particles. In this research striping value of aggregate is equal to 95%.

F. Flakiness and Elongation Test

For Base course the presence of flaky and elongated particle is considered undesirable as they may cause inherent weakness with possibility of breaking under heavy loads. Angular shape of particles is desirable for base course due to increased stability derived from the better interlocking. Thus, evaluation of shape of particles, particularly with reference to flakiness and elongation is necessary.

TABLE 7: FLAKINESS AND ELONGATION TEST RESULT

Name of test	Result
Flaky particle contained in aggregate	6.27%
Elongated particle contained in aggregate	1.27%

III. FLY ASH

The sample of fly ash was collected from Lakhra coal firepower Sindh Pakistan which is running through coal as a fuel. This power plant is about 35 km away from Mehran university of Engineering Technology Jamshoro Sindh. Fly ash created from Lakhra power plant is very fine powder recover from gases create by coal fire electric power generated.

TABLE 8: CHEMICAL ANALYSIS OF FLY ASH

Constituent	Chemical Analysis
SiO3	21.53
Al2O3	15.45
Fe2O3	32.09
SO3	9.98
CaO	6.9
MgO	3.7
Na2O	1.79
K2O	0.16
LOI	8.34

TABLE 9: GRADATION OF FLY ASH

US Standard sieve size	%Passing
1-1/2"(38mm)	100
1" (25mm)	100
¾ " (19mm)	100
½" (12.5mm)	100
3/8" (9.5mm)	100
No.4 (4.75mm)	100
No.8 (2.38mm)	100
No.50 (0.300mm)	69.25
No.200(0.075mm)	24.85

IV. BITUMEN

It is a mixture of hydrocarbons of natural or pyrogenous origin, or a combination of both frequently accompanied by nonmetallic parameters which may be gaseous liquid semi solid and which are completely soluble in carbon disulfide.

TABLE 10: PROPERTIES OF BITUMEN

Property	Definition
Hardness	Property which gives the degree of hardness
Ductility	Property which forms thin film around aggregate
Viscosity	Property which define fluidity of bitumen
Density	Property which show strength i.e Specific gravity
Solubility	Property which shows solubility of binder insolvent
Water content	Property which shows water content in binder
Softness	Temperature where bitumen attains degree of softness.

TABLE 11: BITUMEN TEST RESULTS

Name of Test	Results
The Penetration of the given bitumen @25 ^{0}C	83
Ductility of bitumen @25 ^{0}C	115cm
The Softening of the given bitumen	46 ^{0}C
Specific gravity of the given bitumen	1.05 g/cc
Flash point of the given bitumen	317 ^{0}C
Fire point of the given bitumen	365 ^{0}C

V. BLENDING OF AGGREGATE

In this project trial and error method have been adopted for blending of aggregate. The simplest method of determining proportions is generally the trial and error method. The individual aggregate gradations are examined, and certain percentage of each aggregate is chosen.

TABLE 12: TRIAL BLENDING OF AGGREGATE ASPHALT BASE COURSE

%Used	1-1/2"		1"	¾"	1/2"	3/8"	No.4	No.8	No.50	No.200
Fraction	Average gradation of aggregate fractions									
1-1/2"	100		58.63	44.4	33.2	18.1	-	-	-	-
1"	100		95.14	59.4	29.6	8.16	-	-	-	-
1/2"	100		100	100	100	100	90.5	61.3	20.2	6.62
No.4	100		100	100	100	100	54.0	4.95	0.63	-
Fly ash	100		100	100	100	100	100	100	69.25	24.85
Combine gradation for blend										
1-1/2"	30	30	17.5	13.3	9.96	5.43	-	-	-	-
1"	18	18	17.1	10.7	5.34	1.46	-	-	-	-
1/2"	15	15	15	15	15	15	13.5	9.	3.04	0.99
No.4	29	29	29	29	29	29	15.67	1.43	0.18	-
Fly ash	08	08	08	08	08	08	08	08	5.4	1.98
Blend grading	100	100	86.7	76.0	67.3	58.8	37.2	18.6	8.76	2.97
Job mix		100	87	76	67	59	37	19	9	3
Specification Requirement			75-90	65-80	55-70	45-60	30-45	15-35	5-15	2-7
Mid of Specification			82.5	72.5	62.5	52.5	37.5	25	10	4.5

Asphalt mix is normally termed as HMA (Hot Mix Asphalt) which is consisted combination of uniformly aggregate mix and coat with asphalt cement. To dry the aggregate and obtained enough fluidity of asphalt cement for proper workability and mixing both the asphalt and aggregates must heat to mix the term hot mix.

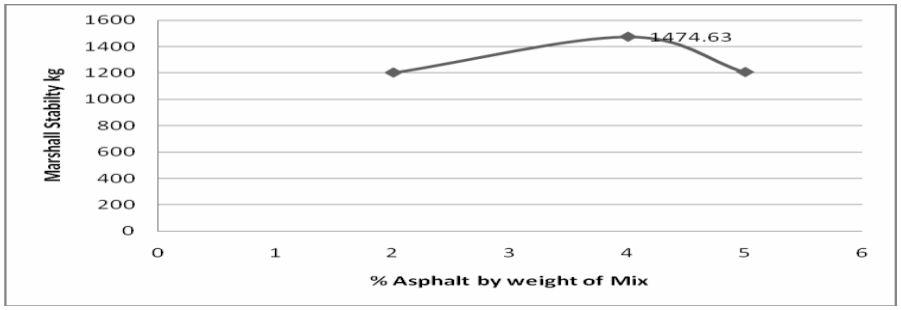

Fig. 1: Marshall stability vs % Asphalt by weight of mix using fly ash

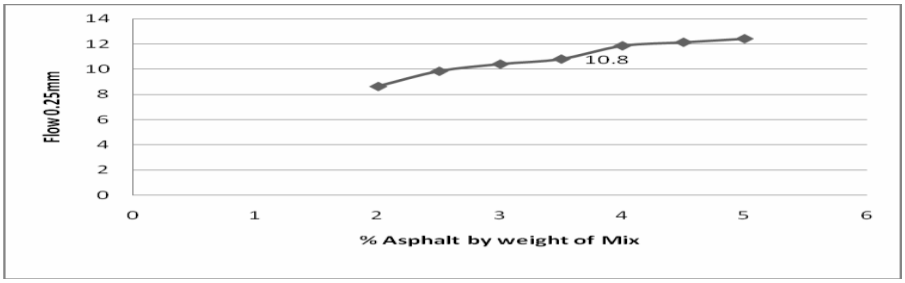

Fig. 2: Flow vs % Asphalt by weight of mix using fly ash

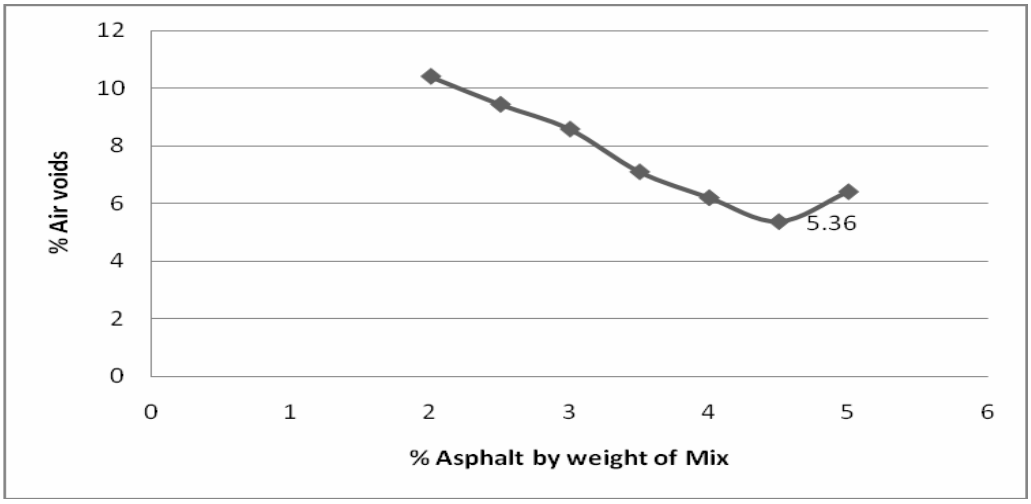

Fig. 3: Air voids vs % Asphalt by weight of mix using fly ash

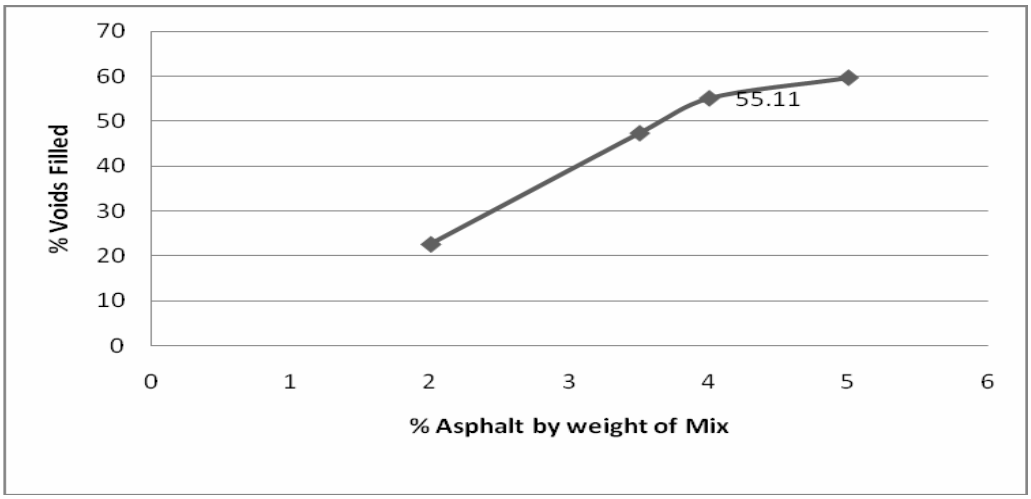

Fig. 4: Voids filled vs % Asphalt by weight of mix using fly ash

Fig. 5: Unit weight vs % Asphalt by weight of mix using fly ash

TABLE XIII: MARSHAL STABILITY ASPHALT MIX DESIGN SUMMARY TEST RESULTS

Asphalt content %	2.0	2.5	3	3.5	4.0	4.5	5.0
Bulk Sp. Gravity	2.23	2.37	2.24	2.264	2.267	2.276	2.236
Max Sp Gr. Paving mix	2.489	2.47	2.45	2.43	2.42	2.405	2.236
Absorbed asphalt % wt total aggregate	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Effective asphalt content %	1.45	1.954	2.457	2.95	3.46	3.97	4.468
Voids in mineral aggregate	13.45	13.62	13.95	13.47	13.79	13.91	15.87
Air voids in comp. min%	10.4	9.43	8.57	7.09	6.19	5.36	6.4
% Voids filled	22.67	30.76	38.5	47.36	55.11	61.46	59.67
Stability in kg	1201.24	1250.5	1283.1	1340.2	1474.6	1222.07	1205.10
Flow (0.25mm)	8.64	9.84	10.4	10.8	11.84	12.12	12.4

VI. CONCLUSION

So, from above discussion it is cleared from experimental study that we can use the fly ash in pavement construction as a 100% replacement of mineral filler. Everyone desire for two things economy and save of time therefore if any road constructed near where huge fly ash is available, we can use the fly ash as 100% replacement of filler. We have loss of only about 8.81% stability.

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Effect of Marble Dust as a Partial Replacement of Cement on Fresh and Hardened Properties of Concrete

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Abstract: **Marble industry has been creating waste that is a concern for most of the marble rich countries. This study makes use of the waste marble to propose an eco-friendly solution to tackle the waste marble problem. In this experimental study, marble sludge was obtained from landfills in Hyderabad, Pakistan. The obtained material was oven-dried and sieved and used for partial replacement of cement. The replacement was done at 0 %, 5%, 10%, 15% and 20% by weight of cement. A total of 75 cubes were casted. An optimum proportion of marble dust was estimated based on workability and compressive strength test results. The results showed around 10% increased compressive strength at the optimum content of 5 % by the weight of cement. 10 % replacement, however, showed comparable results. For the fresh concrete mix, the workability of concrete decreased with increase in the marble dust proportion. 5 % replacement results were comparable with the controlled mix results in terms of workability as it showed a difference of few milimeters. However, 10 % replacement showed a considerable amount of declination in the workability.**

Keywords**: Eco-friendly, Marble Dust, Marble Sludge, Sustainable Concrete.**

I. INTRODUCTION

Concrete is an artificial stone that is a mixture of fine and coarse aggregate bonded with a binder i.e. cement. Civilizations as old as from 6500 BC have used non-hydraulic cement in the past. Greeks and Romans developed hydraulic cement afterwards [1]. It is the most used construction material these days because of its numerous merits which encircle but are not limited to its moldability, adaptable nature, fire resistance and affordability. More than 10 billion tons of concrete is produced annually [2]. With the rise in demand of other basic needs of human like clothing, energy and food, the demand of concrete is also expected to rise by the year 2050 by which the estimated annual amount of concrete is estimated to be 18 billion tons annually [2].

This great amount of concrete production is, however, detrimental as cement industry is believed to produce around 7 % of the total carbon dioxide production of world. Almost one ton of carbon dioxide is produced for one ton of concrete. Moreover, the deposits of natural materials are also in the process of depletion [2].

Construction industry and researchers are trying to address the mentioned problem by searching for new raw materials and by replacing cement with other materials partially [3]. Materials like Fly Ash, Silica Fume, Coal bottom Ash, Municipal solid waste and other pozzolana have been used as partial replacement materials by many researchers [4]. Depending on the composition of replacement materials they tend to control alkali silica reactivity, lessen the greenhouse gases emission and also induce sulfate resistance in concrete [4].

Stones such as Marble, Granite, Limestone, Tavertine, Sandstone and Slate have been in use for years for different purposes – mainly for construction [5]. Marble, however, stands out because of its attractiveness [5]. Pakistan has a rising industry of marble having an estimated amount of 297 billion tons of marble and granite reserves with more than 100 types of colors and varieties [6]. Marble industry is thriving worldwide, but the waste produced is a concern as it amounts much more than to be reserved. Hence, it is dumped in open areas [5]. In the process of mining, cutting and polishing almost 60 – 70 % of the total marble is wasted [5, 6]. About, 20 – 30 % weight of the original brought into factory is converted to marble sludge [7]. This sludge produced is dumped along the roads and processing plants creating landfills. This poses a threat to public health. Dried particles travel through air and water creating water and air pollution. It also clogs the agricultural lands which destroys crops and soils due to its alkaline nature [8].

Different researchers have used marble powder in concrete as aggregate [9] and also as a partial replacement of cement [7, 8]. The addition of marble powder does not only create a filler effect, but it may also be responsible for the production of Calcium Carboaluminates [10]. Ali. A. Abdo et al [7] observed increased compressive strength up to 10 % by replacing cement with marble powder. Manpreet Singh et al [8] and Ali Ergun's [9] experiments also leaded to analogous results. Abdullah Anwar et al [11], on the other hand, observed decline in the compressive strength.

II. RESEARCH SIGNIFICANCE

The main idea of this research is to reduce pollution by decreasing the production of cement and by using waste marble. Partial replacement of cement with waste marble powder was carried out. Fresh and Hardened properties of concrete were investigated. And, an optimum replacement proportion by the weight of cement was concluded.

III. EXPERIMENTAL PROGRAM

a. Materials

Ordinary Portland Cement CEM I 42.5 N that complies with EN 197-1:2000, commonly marketed as Falcon Cement in Pakistan, was used for the study. Natural sand quarried from Bolari with a fineness modulus and specific gravity of 3.01 and 2.63 respectively was used as Fine aggregate for the study. Coarse aggregate from Petaro quarry site was used for the research program. The maximum aggregate size for the study was kept at 20mm.

Fig. 1: Fine and Coarse Aggregate Used for The Study

Marble Sludge was obtained from the local market in Hyderabad. It was dried, broken and then sieved from No. 200 sieve to mix in properly with the fine cement. Lumps were broken prior to sieving. The resulting marble powder was of white color and had a bulk density of 1.55g / Cm^3 .

Fig. 2: Marble Sludge as obtained, Lumps Broken and Sieved from #200

b. Test Parameters and Mixture Proportions

Depending on the amount of marble powder in the concrete a total of 5 concrete mixtures were produced. Cement was partially replaced by waste marble powder at 0, 5, 10, 15 and 20 percentages by the weight of cement. Mixture was designed using the DOE method. The cement content for conventional mixture was 430 kg/ m^3 . Table 1 shows the concrete mix contents.

Table 1: Contents for Concrete Mixture

Mix ID	Cement (kg/ m^3)	Marble Powder (kg/ m^3)	Fine Aggregate (kg/ m^3)	Coarse Aggregate (kg/ m^3)	Water (kg/ m^3)
CC	430	0	630	1180	194
MD-5	408.5	21.5	630	1180	194
MD-10	387	43	630	1180	194
MD-15	365.5	64.5	630	1180	194
MD-20	344	86	630	1180	194

A total of 75 cubes were casted for this study. The compressive strengths of concrete cubes were tested at the curing ages of 3, 7, 14, 28 and 56 days. Mixing was carried out using a rotary mixer available in the Concrete Laboratory, Civil Engineering Department, MUET – Jamshoro.

Fig. 3: Rotary Mixer Used for The Study

A blend of cement and marble dust with appropriate proportion was made. SSD aggregate were first put in the mixer. Fine aggregate was added afterwards in the mixer. A little amount of water from the total calculated amount was also added. The blend of cement and marble dust was later added preceding the addition of residue water. The mixer was allowed to mix until a homogenous mixture was obtained.

Workability was estimated using slump test. A standard slump cone was used and the procedure according to ASTM C143 was carried out. All the cubes were removed from the molds after 24 hours and then cured in water until their specified testing date.

IV. TEST RESULTS AND DISCUSSION

a. Fresh Properties

Workability was determined to evaluate the fresh properties of concrete. Workability of mixtures with 0%, 5%, 10%, 15% and 20% replacement were checked using slump test. The overall results show a decline in the slump values. However, the slump result of MD-5 was comparable to that of the CC. Table 2 shows the workability in terms of slump values for the five mixtures.

Table 2: Workability of Concrete Mixes

Mix ID	Slump Value (mm)
CC	33
MD-5	26
MD-10	18
MD-15	13
MD-20	12

It can be noticed that the MD-5 when compared with the CC had 21 % less workability. The values for MD-10, MD-15 and MD-20 even go higher up to 45.5 %, 60 % and 63.6 % respectively. The decline in the workability has been illustrated in the figure 4.

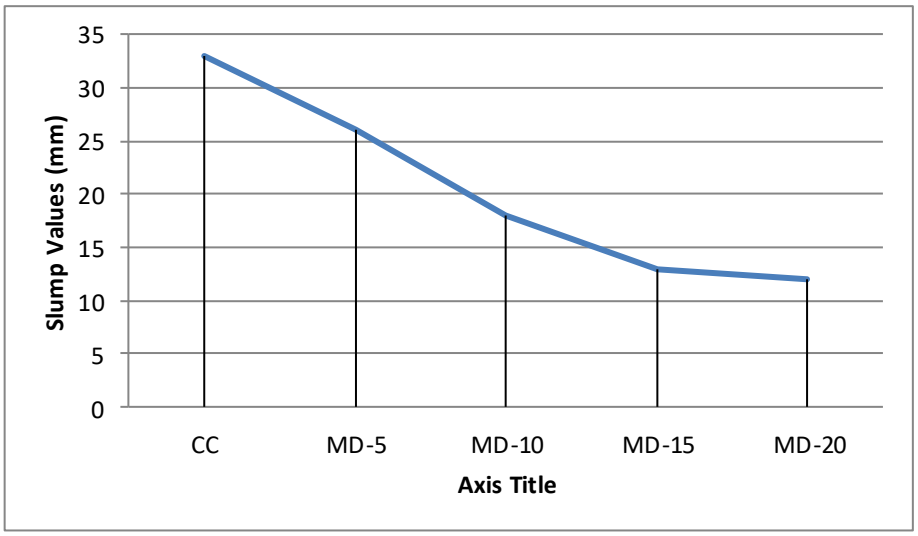

Fig. 4: Workability of Concrete Mixtures

b. Hardened Properties

For hardened properties of concrete only compressive strength was checked. Unlike workability which showed a decline for all replacement percentages, compressive strength test results tend to differ from the same scenario. The results show an increment of compressive strength for MD-5. However, the compressive strength tends to decrease for MD-10, it can be seen the results are still comparable.

Figure 5 gives an illustration of comparison of results of different concrete mixtures.

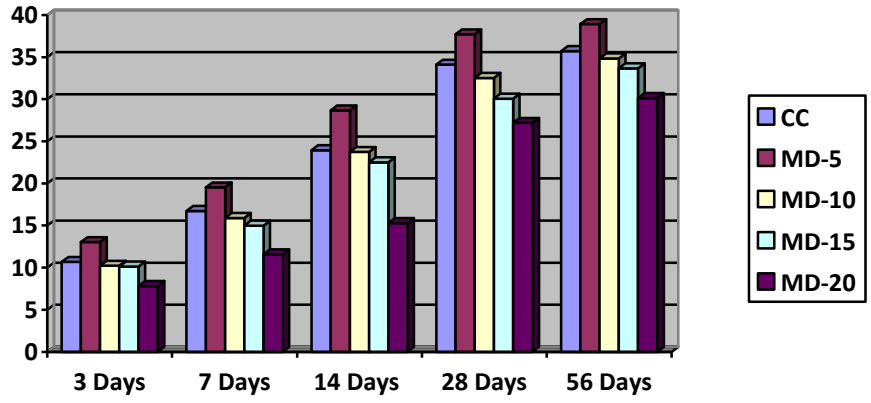

Fig. 5: Compressive Strength (MPa) Comparison between Concrete Mixes at Different Curing Ages

Compressive strength of MD-5 remained higher throughout the tenure of observation. At 28 days, the compressive strength of MD-5 was higher than CC by 10.6 %. However, MD-10, MD-15 and MD-20 had a lower compressive strength by 4.6 %, 11.84% and 20.3 %, when compared with CC, respectively.

Table 3 shows the values of compressive strength of concrete mixtures at different curing ages.

Table 3: Compressive Strength of Concrete Mixtures at Different Curing Ages

Mix ID	Compressive Strength at 3 Days (MPa)	Compressive Strength at 7 Days (MPa)	Compressive Strength at 14 Days (MPa)	Compressive Strength at 28 Days (MPa)	Compressive Strength at 56 Days (MPa)
CC	10.68	16.74	23.94	34.11	35.71
MD-5	13.03	19.52	28.67	37.72	38.92
MD-10	10.23	15.90	23.74	32.54	34.84
MD-15	10.12	14.99	22.51	30.07	33.67
MD-20	7.82	11.58	15.29	27.19	30.14

V. CONCLUSION

From the study it can be concluded that the workability of the concrete decreases by a good amount for which suitable plasticizers are required. 28-day compressive strength increases up to 10 % if we replace 5 % of cement with Marble Dust. We can conclude that the 5 % is the optimum content to replace cement with marble powder.

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Survey and Evaluation Study for Determining Flexible Pavement Failures of Hyderabad – Hala Road N-5, Pakistan (KM 167+000 to KM 172+000)

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***Abstract*: An effective transportation system has a profound effect on the national development of a country. However, in recent years due to axle overloading and improper maintenance of pavements, the roads in Pakistan are subjected to structural cracking and functional distresses. The objective of this paper is to investigate and conduct survey to evaluate the flexible pavement distresses and develop guidelines to reduce the probability of premature pavement failures in the future rehabilitation projects. A section of Indus highway (N-5) from Hyderabad to Hala (Km 167+000 – KM 172+000) was surveyed and factors leading to failures were investigated. Systematic approach was followed to determine the causes of pavement failures. The investigations carried out in this study included the site survey, analysis of traffic, coring of samples and evaluation of materials used in the asphalt mix design. It was diagnosed that the improper selection of materials and the plying of heavy traffic were the likely root causes behind the observed distresses in the pavement. In order to curtail the failures in future projects, it is recommended that road pavements are structurally enhanced to withstand heavy loads and qualified site personnel are recruited for monitoring of road maintenance.**

***Keywords*: Aggregates, Axle overloading, Cracking, Pavement distresses**

I. INTRODUCTION

An effective transportation system is correlated with the national development of a country. A proper communication channel plays an important role in reviving the economic and social sectors of a state as it serves in creating more opportunities in the ever-expanding domestic markets [1]. The traffic volume in Pakistan has grown manifold in recent years, and a major intensity of the traffic load is being absorbed by the National highway N-5 which carries almost 50% of all inter urban traffic of the country [2]. The National highway N-5 serves major areas of Pakistan by passing through Punjab, Khyber Pakhtunkhwa (KPK), and Sindh province. It extends about 671 km in the province of Sindh and is subjected to all kinds of local traffic in the province. However, a large number of major interstate and smaller projects serving National highway N-5 in Sindh have exhibited pavement distress in the recent times due to over loading of trucks and the loss of materials characteristics. The main types of pavement distresses observed on the N-5 highway are either deformation failures or surface texture failures. Currently, in Pakistan there are 138000 registered commercial trucks (3% of total vehicles) travelling on the country's roads. Since there are no proper manufacturing criteria in Pakistan; the types and makes of these trucks vary accordingly [3]. An axle load study (NTRC) was carried out which indicates that 80% of trucks loaded above the design limits of 8.20 tons and 40% above the axle load limits of 12 tons [4]. The lack of load restrictions policies has deteriorated the conditions of roads in Pakistan and thus the situation demands for immediate enforcement of axle load restrictions policies and rehabilitation of failed road sections [5].

The N-5 Hyderabad– Hala road completed in 1987 serves as a major route connecting the interior areas of Sindh province. The existing Hyderabad-Hala highway road is a 4-lane facility presented with local traffic throughout the entire span of the highway. The road is engaged with large number of vehicles coming from other parts of the Sindh province, especially from Karachi, Hyderabad, Thatta and nearby regions. The movement of heavy traffic on the road had caused it to fail previously in 2010. However, the road was soon rehabilitated by NHA (National Highway Authority of Pakistan). The existing condition of the road surface is not convenient for high traffic load and due to the loss of material characteristics the need for the rehabilitation of the N-5 Highway road (KM 167+000 TO KM 172+000) is necessary to fulfill the future travel demands and to incite economic activity. The road section comes under the improvement program of NHIP National Highway Improvement Program). The recent rehabilitation program of the road was proposed in 2016 and the contract for rehabilitation work was let in 2017.

The aim of the research is to determine appropriate site investigation methods and testing to identify source conditions that have led to premature failures on the Hyderabad – Hala road section on N-5 highway.

II. METHODOLOGY

A systematic approach was followed during the research in order to identify the causes of premature pavement failures on the Hyderabad-Hala road section. The conceptual design of this research consists of analysis of the field and laboratory investigations of the core samples obtained from the road section.

A. Site Visit

The Hyderabad – Hala road section (KM 167+000 to KM 172+000) was visited to identify sources of conditions that have led to pavement distress; and to evaluate the design and construction of the road. The chainage section (167+000 KM to 172+000 KM) of the road ranged from Hatri to Matiari. The road section is a 4-lane highway and it manifested several signs of pavement failures, primarily including fatigue cracking and rutting failure. Some of the information collected from the initial site visit included the photographs of the existing pavement conditions and visual evaluation of the condition of the pavement surface. The pavement distresses observed on the road are shown in fig. 1–3.

Fig. 1: Pavement distresses observed on Hyderabad - Hala road

Fig. 2: Fatigue cracking on the pavement

Fig. 3: Rutting failure

B. Pavement Distresses

The major part of the road section exhibited rutting to depths of 1 inch (25 mm) and greater. Potholes and alligator cracking were observed along the travelling path of the road. The longitudinal and transverse cracks were observed at the top of the surface but occasionally they had penetrated through the full depth of the wearing course. Also cracks of different sizes ranging from small cracks to large cracks of 25 mm were observed on the road section.

C. Rehabilitation Activity

The periodic maintenance work of the Hyderabad – Hala road section was proposed in 2016 by National Highway Authority (NHA) under the improvement program of National Highway Improvement Program (NHIP). The typical cross-section proposed for the rehabilitation of road is shown in fig. 4. It is indicated that five inches (130mm) of the existing

HMA surface is to be milled and replaced with 80 mm thick Asphaltic base Course of Class-A and 50 mm thick Asphaltic Concrete Wearing course of Class-A. Also, it is recommended that double Surface Treatment is to be carried out on the outer shoulder. Additionally, 2% drainage slope is provided for the carriage way and inner shoulder and 4% drainage slope is provided for the outer shoulder of the road.

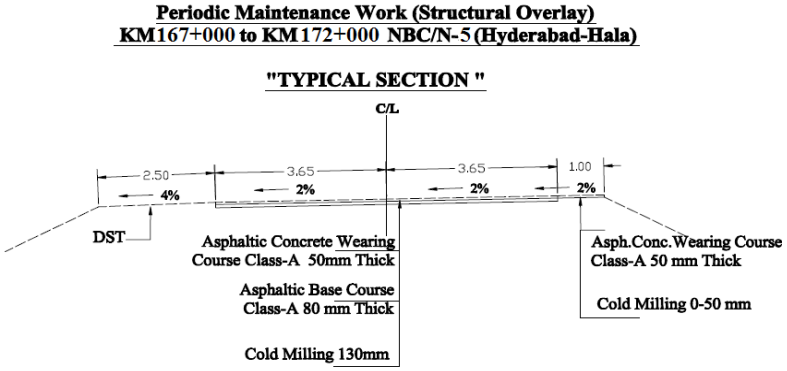

Fig. 4: Cross-section of Hyderabad - Hala road

D. NHA Records Review

The feasibility study and project rehabilitation reports for the Hyderabad-Hala road section were reviewed with the assistance of NHA contract administration personnel [6]-[7]. The records review helped in identifying the factors that might have influenced the failures in the road. The data tabulated in Table 1 provides the summary of the findings from records review.

Table 1: Summary of records review

Project Description	
Year of Rehabilitation	2017
Highway type/Section	Indus Highway N-5 (167+000 KM to 172+000 KM)
Number of Lanes	4
Year of original construction	1987
Number of contracts let on this project	1987, 1996, 2010,2017
Climate Zone	Hot, Arid (Very dry)
Pavement Rehabilitation Design Records	
Subgrade soil type	Alluvial Soil
Design subgrade modulus (Average/range)	34 MPa (5000 psi)
Subgrade soil moisture content	Traces of water logging and salinity
Deflection testing performed?	Yes
Pavement Design Recommended	WC: 50mm Asphaltic concrete wearing course (Class A) BC: 80mm Asphaltic base course (Class A)
Pre-Design Pavement Condition Survey Records	
Was a detailed condition survey performed?	Yes
What was the predominant distress noted in the project?	Rutting (both directions)
What are the other types of surface distress noted?	Fatigue cracking, few patches, raveling, transverse and longitudinal cracking
Was coring performed?	Yes
Was stripping evident in core? If yes, at what depth/layer?	Yes (few cores, initial stages)
Were rutting measurements taken? If so, what was the average/range of rutting?	Yes; Average: 1", ranging from 1" to 2"
What was the condition of shoulders? (Poor, Fair, Good)	Fair
Maintenance Records	
Post construction conditions – maintenance personnel comments on prime cause of distress	Rutting primary distress and potholes. Maintenance personnel have been repairing the distress with patches.
Post Construction Records (initial site visits)	
Distress types	Patches, shoving and potholes

E. Data Collection

The necessary data required for the research work was collected from the site of the project and the office of NHA located in Jamshoro. The core samples of the failed road section were obtained with the help of Automated Core Drill (ACD)

available at the site. Further, the copy of Job Mix Formula of the road section was collected from the office of NHA for detailed investigations.

F. Field Sampling

The field sampling consisted of cutting cores from the pavements. Coring was accomplished by NHA personnel as observed in Fig.5 – 7. Cores were obtained at depth of 130 mm and its details are indicated in Table 2.

Table 2: Cores locations and dates obtained for the Hyderabad - Hala road rehabilitation project

Location	Date	Number of cores Obtained	Typical distance between cores (miles)	Notes
N-5 (167+000 KM to 172+000 KM)	August 2017	8	0.3	Several cores obtained at intermediate locations near structures.

Fig. 5: Extraction of core samples

Fig. 6: Depth of core

Fig. 7: Core Samples

G. Job Mix Formula

The Job Mix Formula (JMF) of the Hyderabad - Hala road section N-5 was obtained from the NHA office Jamshoro. It provided details of the materials used for the production of Hot Mix Asphalt (HMA). The Job Mix Formula of the road provided the target values of gradation, aggregate properties and asphalt binder content with allowable specification bands.

H. Laboratory Investigations

The cores obtained from the failed road section of Hyderabad – Hala road were investigated to determine various characteristics of an asphalt concrete pavement for construction quality testing and quality assurance testing. The laboratory tests were carried out on the aggregates and the binder extracted from the core samples. The review of pavement mix design was done by comparing the properties of extracted aggregates and binder with the available data in the job mix formula [8].

I. Extraction Test

The extraction test was carried out to extract the two basic constituents of asphalt pavement core samples that are the stone aggregates and the Asphalt binder content (Bitumen). In order to carry out analyses on the aggregates and bitumen used in the making of road, aggregates and binders were extracted from the core samples of asphalt pavement using an organic solvent [9]. ASTM D-2172 method was used for the extraction test and Trichloroethylene was used as an extractant to ensure proper separation of binder from aggregates takes place.

J. Sieve Analysis of Aggregates

The sieve analysis experiment was carried out on the aggregates obtained from the core samples. The gradation of aggregates was carried out as per AASHTO T-27. The sieve analysis was then compared with the job mix formula of the road section in order to validate the passing percentage of aggregates within the upper and lower passing limits of job mix formula [10].

K. Specific Gravity of Aggregates

The specific gravity test was carried out on the aggregates obtained from the core samples as per AASHTO T-85. The test was carried out on aggregate sample size 19-12 mm. The main purpose of this test was to evaluate the strength of the aggregates used in the paving of roads. Aggregates having specific gravity close to 2.7 are mostly preferred by NHA for the construction of roads.

L. Los Angeles Abrasion Test

The Los Angeles Abrasion test was conducted on the aggregates obtained from the core samples to examine the toughness of aggregates. The test was carried out as per AASHTO T-96. The maximum permissible limit of Los Angeles Abrasion value is 40% [11].

M. Soundness Test

The test was carried out to analyze the resistance of aggregates to solution weathering action. The test was carried out as per AASHTO T 104. The aggregates were soaked in saturated solution of sodium sulphate [12]. The average loss of aggregate after 10 cycles were then determined.

III. RESULTS

A. Coring activity

In general, 8 cores were obtained for this project. Visual examination of cores obtained from the projects provided the evidence of stripping, layers with less asphalt binder and presence of voids.

B. Extraction Test

The Bitumen content used in the pavement design was calculated after the extraction of aggregates and binder from the core samples. The results of the two core samples are tabulated in Table 3 and Table 4.

Table 3: Bitumen Content of 1st core sample

Weight of core before extraction (gm)	Surface Area of Core (m^2)	Weight of aggregates after extraction (gm)	Weight of Bitumen (gm)	Bitumen Content %
1260	0.057	1230	30	2.439

Table 4: Bitumen Content of 2nd core sample

Weight of core before extraction (gm)	Surface Area of Core (m^2)	Weight of aggregates after extraction (gm)	Weight of Bitumen (gm)	Bitumen Content %
1236	0.051	1185	51	4.304

From the above results it is observed that the bitumen content obtained from the two core samples vary significantly. The optimum bitumen content (%) specification provided by NHA for preparation of Hot Mix Asphalt (HMA) is 4.06%. The bitumen content obtained from first sample is 2.439%. It is quite low as compared to the range of bitumen content provided by NHA. The low bitumen content of the first sample indicates that segregation of aggregates has taken place, and this led to cracking to take place in pavement. Further, the second core which was extracted few miles ahead had bitumen content of 4.304%. The high bitumen content of the second core sample led to bleeding failure on the road section.

C. Sieve Analysis of Aggregates

The results of sieve analysis of aggregates are mentioned in Table 5 and Figure 8.

Table 5: Sieve analysis of aggregates obtained from core

Extraction	(1)	Sieve Inches	Cumulative Retained	% Retained	% Passing	JMF Limits	
Mass of Sample (gm)	1260	1”	145	11.78	88.21	78	92
Mass of Filter before Extraction (gm)	30	¾”	289	23.49	76.50	70	85
Mass of Filter after Extraction (gm)	32.3	½”	576	46.82	53.17	48	64
Filler in the Filter (gm)	2.3	3/8”	695	56.50	43.49	38	53
Mass of extracted Aggregate (gm)	1227.7	No.4	773	62.84	37.15	32	45
Mass of Total Aggregate (gm)	1230	No.8	893	72.60	27.39	19	39
Mass of Bitumen (gm)	30	No.50	1135	92.27	7.72	4	13
Percent Bitumen %	2.439	No.200	1207	98.13	1.86	1.7	6

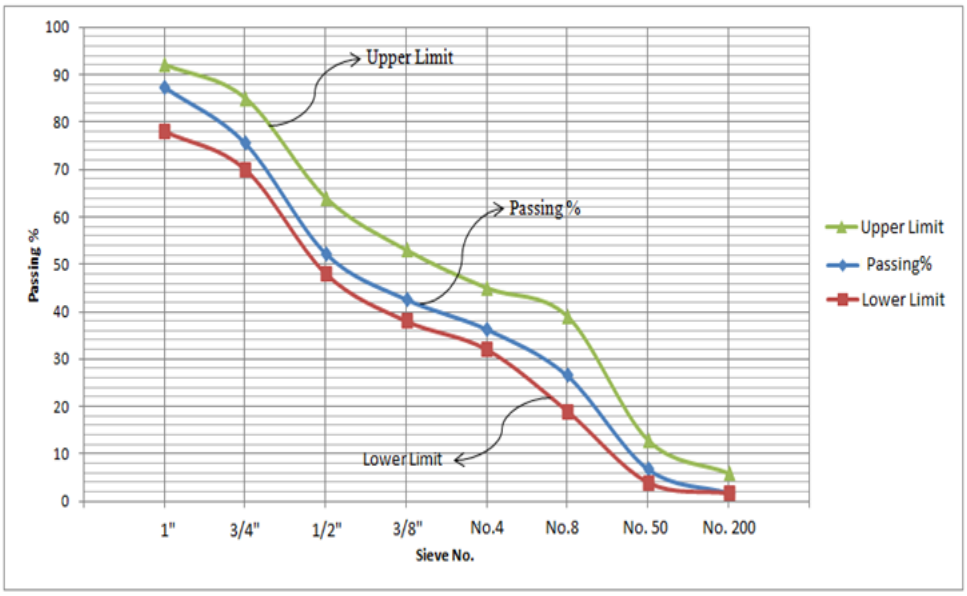

Fig. 8: Sieve Analysis of aggregates

The results of the gradation test shown in Table 5 indicate that the size of the coarse aggregates used for the preparation of road are within the specified upper and lower limits of job mix formula of the road section. It can be observed from Fig. 8 that aggregates were passing within the specified limits of job mix formula.

D.Specific Gravity Test

The weight of oven dry samples and Saturated Surface Dry samples (SSD) of aggregates were determined to calculate the specific gravity of aggregates. The specific gravity results of the aggregates were then compared with the specific gravity results mentioned in job mix formula. The Table 6 provides the specific gravity of aggregates carried out on sample size 19-12 mm mentioned in job mix formula. The Table 7 provides the laboratory testing of specific gravity on aggregates of size 19-12 mm obtained from core samples.

Table 6: Specific Gravity mentioned in Job Mix Formula

Source of material: 19 – 12 mm		
A	Weight of oven dry samples of Aggregates in Air (gm)	2000
B	Weight of dry samples of Aggregates in Air (gm) (SSD)	2018.1
C	Weight of samples of Aggregates in Water (gm)	1265
D	Bulk Specific Gravity D = A / (B – C)	2.65
E	Bulk Specific Gravity (SSD) E = B / (B – C)	2.68
F	Apparent Specific Gravity F = A / (A – C)	2.72
G	Water Absorption G = (B – A)	18.1
H	Water Absorption % H = (B - A) / A	0.90

Table 7: Specific gravity test results of aggregates obtained from core samples

Source of material: 19 – 12 mm		
A	Weight of oven dry samples of Aggregates in Air (gm)	2000
B	Weight of dry samples of Aggregates in Air (gm) (SSD)	2031
C	Weight of samples of Aggregates in Water (gm)	1164
D	Bulk Specific Gravity D = A / (B – C)	2.31
E	Bulk Specific Gravity (SSD) E = B / (B – C)	2.34
F	Apparent Specific Gravity F = A / (A – C)	2.39
G	Water Absorption G = (B – A)	31
H	Water Absorption % H = (B - A) / A	1.55

The results of specific gravity test indicate that the aggregates used for the construction of roads were not having adequate strength to withstand the heavy vehicular load. The low apparent specific gravity of 2.39 % states that the aggregates used

were of substandard quality and did not meet the criteria of the specifications mentioned in job mix formula. The low strength of the aggregates is the reason why the road section failed prior to its design life.

E. Los Angeles Abrasion Test

The Los Angeles abrasion values obtained from the laboratory investigations were compared with the Los Angeles value of the aggregates mentioned in the job mix formula to evaluate the toughness of aggregates. The Table 8 indicates the Los Angeles abrasion values of aggregates mentioned in the job mix formula and Table 9 provides the details of Los Angeles abrasion test carried out on aggregates obtained from core samples.

Table 8: Los Angeles Abrasion value of aggregates mentioned in job mix formula

Los Angeles Abrasion Test	
Grading used	B
Mass of sample before test (gm)	5000
Mass retained on sieve size 1.70 mm (gm)	4107
Mass passing sieve size 1.70 mm (gm) (B - C)	893
LAA Value % [(B – C) / B] × 100	17.86

Table 9: Los Angeles Abrasion test results of aggregates obtained from core samples

Los Angeles Abrasion Test	
A. Grading used	B
B. Mass of sample before test (gm)	5000
C. Mass retained on sieve size 1.70 mm (gm)	2917
D. Mass passing sieve size 1.70 mm (gm) (B - C)	2083
E. LAA Value % [(B-C) / B]× 100	41.66

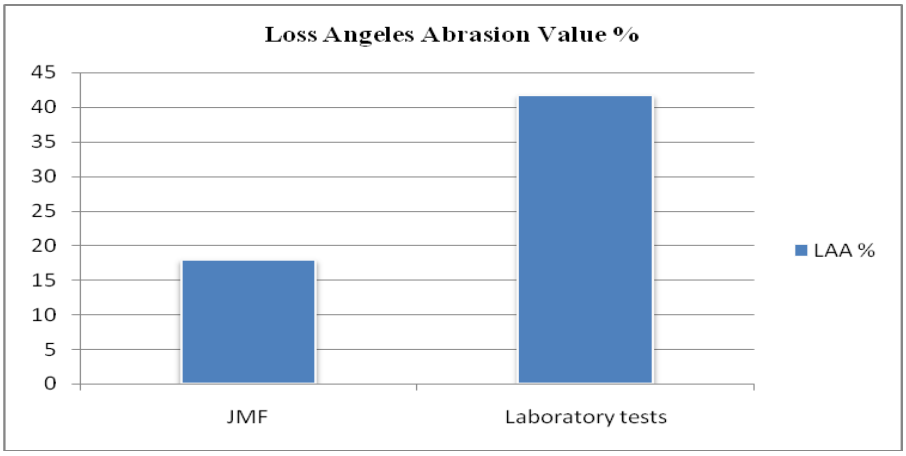

Fig. 9: Loss Angeles Abrasion Value %

The results of laboratory testing in Table 8-9 and Fig.9 indicates that the aggregates used in the making of asphalt pavement had exceeded the maximum permissible limit of Los Angeles abrasion test value of 40 %. The aggregates showed relatively low resistance to wear and demonstrated undesirable abrasion and toughness characteristics.

F. Soundness Test

The soundness value obtained from the laboratory investigations was compared with the soundness value of the aggregates mentioned in the job mix formula to evaluate the resistance of aggregates to weathering actions. The data in Table 10 indicates the soundness value of aggregates mentioned in the job mix formula and Table 11 provides the details of soundness test carried out on aggregates obtained from core samples.

Table 10: Soundness value mentioned in job mix formula

Sieve Size		Grading Retention % of Original Sample	Weight Test Fraction Before Test	Weight Test Fraction After Test	Loss in Weight After Test	Actual Loss After Test %	Corrected Average Weight Loss%
Passing	Retained	A	B	C	D=(B-C)	E=(D/B)×100	F=(A×E)/100
3/8”	#4	88.01	300	295.23	4.77	1.59	1.40

Table 11: Soundness tests results of aggregates obtained from core samples

Sieve Size		Grading Retention % of Original Sample	Weight Test Fraction Before Test	Weight Test Fraction After Test	Loss In Weight After Test	Actual Loss After Test %	Corrected Average Weight Loss%
Passing	Retained	A	B	C	D=(B-C)	E=(D/B)×100	F=(A×E)/100
3/8”	#4	62.84	300	282.34	17.66	5.88	5.05

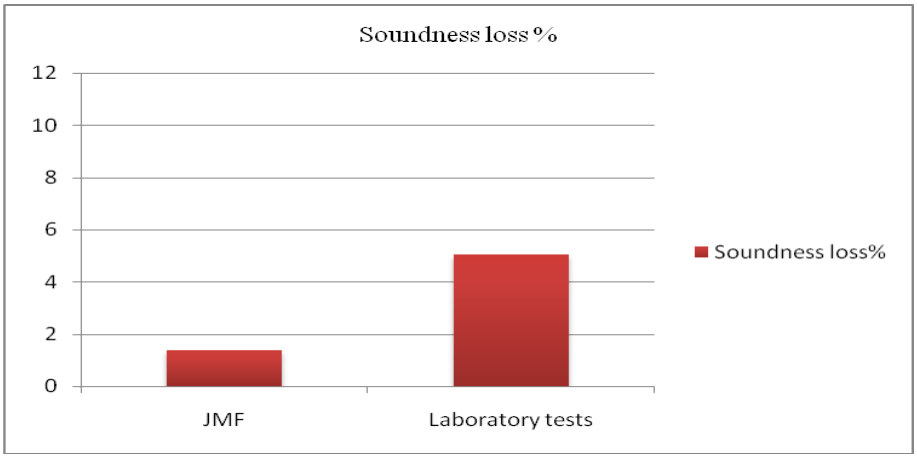

Fig. 10: Soundness loss%

It can be observed from the results of soundness test and Fig. 10 that the average weight loss percentage of aggregates after 10 cycles was 5.05%. The average weight loss percentage of aggregates passes the maximum permissible limit of soundness value of 12%.

IV. CONCLUSIONS

The research methodology applied in this paper presents a suitable method to evaluate and determine the failures on the flexible pavement road. A systematic approach was followed by comparing the properties of core samples and Job Mix Formula of Hyderabad – Hala road. The laboratory investigations were carried out on the aggregates extracted from the core samples used in the upper layers of the pavement. It was identified that some of the properties of aggregates did not match the readings mentioned in Job Mix Formula. The aggregates exceeded the maximum limit of 40% abrasion value and the low specific gravity of 2.39 suggested that the aggregates used for the road section were not suitable to sustain the high vehicular load imposed on them. The uneven spraying of bitumen was another cause of the failures of pavements and it led to bleeding and segregation problems. It is thus concluded that the usage of substandard aggregates and binding materials on the Hyderabad – Hala road section along with the high vehicular traffic load were the prime reasons that led to the failure of the road section.

V. RECOMMENDATIONS

It is recommended that the destructive tests such as coring, and component analysis techniques should be carried out to check the structural capacity of the pavement and to evaluate the properties of materials used in the paving of road. The selection of aggregate and asphalt binder content should be as per the specifications of the job mix formula of the road section. It is also suggested that an inspection should be carried out by the management team to evaluate the performance of the road.

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Human Resource Management Practices in Construction Industry of Sindh

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***Abstract*: Human Resource (HR) is one of the key resources which plays vital role in achieving organization goals of any firm and project. It is very imperative to manage human resource. Thus, human resource management (HRM) is considered very important area as it aims in assigning the work element to the most suitable person. There are several practices and model adopted by different organization. This paper is aimed to give insight view regarding HRM practices adopted construction industry. It involved comprehensive literature review in identifying various HRM models and practices adopted in construction industry worldwide. A group of experts from five large construction firms of Karachi involved in HRM process were interviewed using structured questionnaire to assess relevancy of the identified HRM practices and model with construction industry of Pakistan. The findings of this paper revealed that in Pakistan there are several practices adopted, however no specific model is used. This paper has also given clear understanding of HRM Practices implemented by various organizations.**

***Keywords*: Human Resource Management, Construction Industry, Sindh.**

I. INTRODUCTION

Human Resource Management (HRM) is a practice which focus and targeting on finding the right people for the right jobs which is the key criterion towards the achievement of organizational goals [1]. Since, construction works are labour oriented and involve huge amount of workforce with a variety of qualities specially focusing to boom the economies [2]. Taking the construction as a proper task along with talented experts ensures the timed accomplishment with targeted cost. Good communication and cooperation among the employees are established by HRM [3]. Hence, HRM is being popularized and getting to be a need of organizations as high valued entity maintaining benefits [4]. The smart approach of organization can influence right employees stay longer on right jobs to gain optimal output / performance and it depends on the organization's policies and incentives [5]. Firms beliefs how to tackle their employees, therefore its need to be well organized their HR policies to boost its capacity to maintain the right talent of employees to recruit it, with essential competitive advantage [5]. In kingdom, normally there is lack in HRM for its improvement [6]. In perspective of that, this research work reviews the HRM practices of construction industry and identify the state and lack for enhance their HRM practices [16]. Enhanced HRM practices enable wide competitive advantage in industry [7].

In supporting the implementation of proper human resource management various guideline and models have been developed. This study is aimed to identify the organizations of Pakistan especially Sindh province-based construction firms which implement human resource management practices and models.

II. LITERATURE REVIEW

A. Human Resource Management

Human Resource Management (HRM) is crucial for all kinds of industries including construction companies. Every construction organization must develop their HRM besides establishing technical skills. HRM ensures deploy the best individual for a project based on the level of expertise. The desired or optimal projects are always and only possible due to HRM's SOP which ensures selection of employees / people / workers focusing at their performance, even training them, setting their compensation and incentives while maintaining their complete record [8]. Construction works are very complicated and need skilled workforce and hence bigger organizations are adopting practices of HRM which have turned up good outcomes [9].

Dominant organizations in the tough spirited environment of today force their HR departments to take a part in effective roles. Many jobs they have done in good manner way which has helped them to improve firm's efficiency, boost the quality of job life in the firm, implement with all the require rules and regulations allied to supervise HR effectively, attain competitive benefit, and boost labor force elasticity [10]. In all organizational strategy, designing HRM is playing key role. The companies can only prolong competitive edge by continuously seeking for better and cost-effective practices that is difficult for other firms to catch quickly [11] and competitive advantage in human resource strategy is very much important [12]. Firms invest more money in training and development of staff with advance technology and work practices. A business strategy on the basis of theoretical work shows importance of HRM for gaining competitive edge [13].

The approach of HRM in management is very different to others approaches and it struggles to attain the set targets, commitment with employee, adaptability/elasticity and superiority. The set goals could be to attain the firm continue their strategy and implemented it more effectively. Loyalty of employee, satisfaction of job, and enthusiasm will be view as significant element of HR to firm performance as cited by [14]. Management practices can be improved by quality Human resource management. It will reduce cost and time involved in small labor issues in construction industry [1]. In a construction market which is mostly based on labor and influenced by the productivity for evaluation, it is very much difficult to earn best HR value in company that counts on overall performance [15].

B. Human Resource Policies

Setting the line of action in a written document is a policy. All the employees and whole organization is abided by it. A policy embraces guidance and plan being a company agenda on a paper which seeks for practicality and implementation. The policy somehow ensures the risk-free decision making [16]. HR Philosophies is a system which embraces 5 processes as HR Philosophies (defining the main ethics and leading principles take on in managing workers); HR Strategy (direction of HRM); HR Policies (guidance for the implementation of policies; Strategies are to be applied on particular areas of HRM); HR Processes (comprises of official / professional ways and techniques to put HR strategic plans and policies to get desired outcomes) and HR Programs (to ensure the plan and strategies, for the implementation of HRM policies and practices within the defined guidance and procedures) [17].

HRM policies help finding the behaviors in taking a position on any issue. Ref. [17] summarized 10 steps for formulation and implementation of HRM policies as:

1) Accept the corporate culture and its main values.
2) Review present policies, on paper and in oral form. The policies of HR will be present in any firm,
3) Review exterior influences, HR policies main focus is on the influence of employment constitution and also the set of laws of practices issued by professional institutions.
4) Review every region if the latest policies are desired or present policies are not enough.
5) Managers take inspection, priority wise first from the top, according to their views about HR policies and where they would be thinking there is the need of improvement.
6) Find out the vision of workers regarding HR policies; particularly make it possible to implement it on merit and fairly basis consistently.
7) Find out the ideology of union council.
8) Review the knowledge attained from above seven steps and make draft policies.
9) Meeting and converse with management and union representatives until they have the same opinion on policies.
10) Converse the policies, along supervision notes for implementation if required. In addition, this announcement with training.

C. Human Resource Management Models

Several researchers have worked to develop models to implement smooth and universal human resource practices. Among these models, one of the popular works is known as Michigan or Matching model. This model was developed by Fomburn of the Michigan School in 1984. Framework of this model is presented in figure 1.

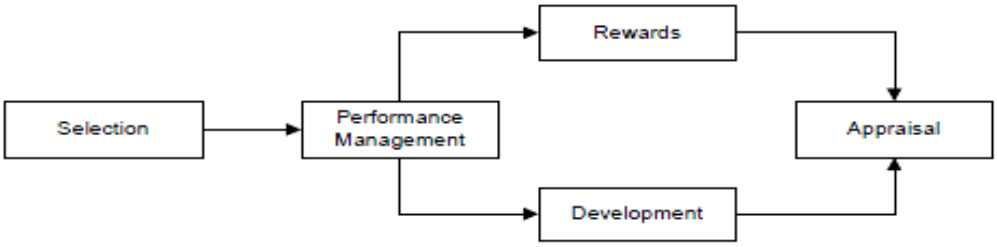

Fig. 1: The Michigan Model (Source; ref [as cited in 16])

As seen from figure 2, Michigan or Matching model provides an accurate ideology regarding HR, however, this closed HR system did not consider any outside influence and totally different for organizational development studies presently. It was the basis of designing further models which can overcome these lacking. It was very much useful for future development concept. After this model, a new development was introduced by [16 as in 17]. This development was using the style of Harvard presentation and hence was popularized as Harvard framework as shown in figure 2.

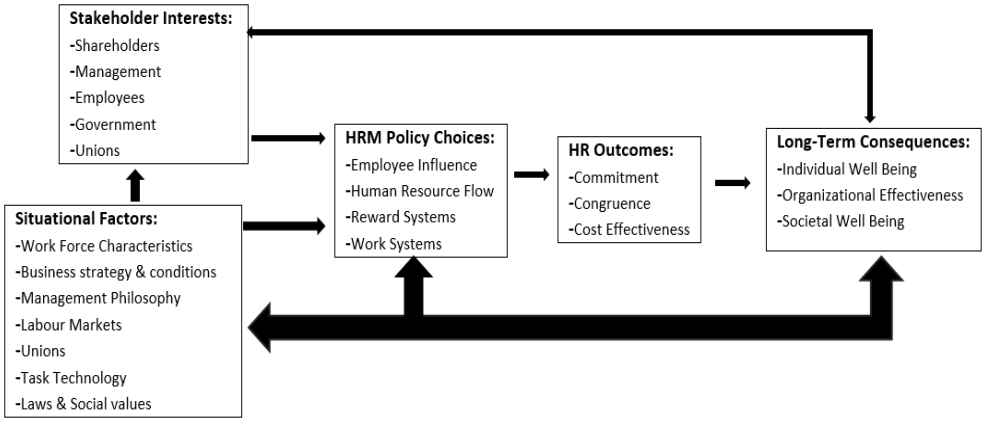

Fig. 2: The Harvard Framework (Source; ref [18 as cited in 19])

In Harvard framework, the thought was that many issues need large, significant strategy with clear understanding of problem and it became the basis of long term plan for staff management. It also realized to consider employees as key assets for growth instead of cost. Later on in 1987, Guest developed a new model known as guest model as presented in figure 3.

HRM Strategy	HRM Practices	HRM Outcomes	Behavioural Outcomes	Performance Outcomes	Financial Outcomes
Differentiation (innovation)	Selection Training Appraisal	Commitment	Effort/ Motivation	High: Productivity Quality	Profits
Focus (Quality)	Rewards Job Design	Quality	Cooperation	Innovation Low: Absence	
Cost (cost-reduction)	Involvement Statutes and Security	Flexibility	Involvement Organizational Citizenship	Labour turnover Conflict Customer Complaints	Return on Investment

Fig. 3: The Guest model of Human Resource management (HRM) (Source; ref [20])

The field of HRM is easy to understand through this model which clearly suggests inputs and outputs. This model can be perceived as the improved version of Harvard model in which four policy goals can be tested:

- Strategic Integration: He believes that organization should be capable to dissolve HRM issues and use it for planning strategies, make sure that different aspects are linked to each other that is useful for line managers in their operations.
- High Commitment: self-commitment to achieve goals with strong sense of appropriate attitude for enterprise growth.
- High Quality: The behavior of manager depends on how better-quality goods and service can be produced which includes employee management with their training to make them more suitable for the job.
- Flexibility: the functions of the organization should be flexible, and its structure should be ready to modify for innovative changes with good capacity.

Until now, the main problem was that most of the developments in HRM concept were based on the American studies. Warwick Model came from Hendry and Pettigrew who belonged to Centre for corporate studies and change at Warwick University and presented a new model for HRM practices as in figure 4.

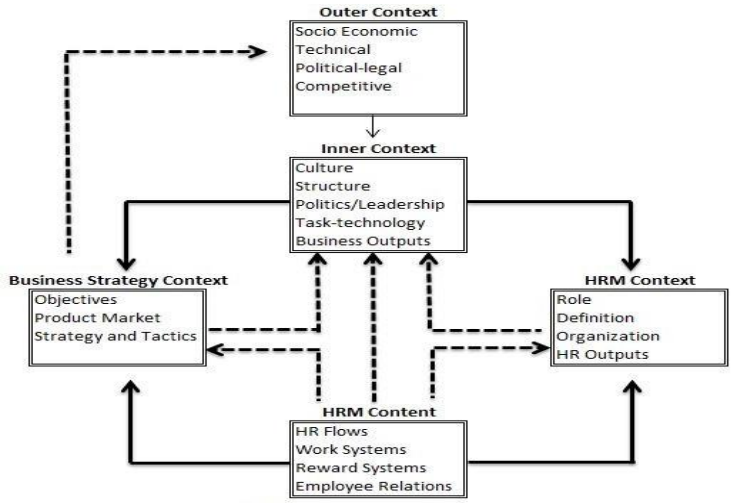

Fig 4: The Warwick Model (Source; ref [21 as in 16])

This model is different from Harvard and Michigan models because it shows European styles and management traditions. The balance between external and internal context is achieved by organization in this case for better experience and high productivity. Model realizes large context of HRM operations and puts importance in the skill and jobs due to which HRM becomes key Function [9].

III. METHODOLOGY

This study involved the development of questions for survey and interview based on literature review. The targeted respondents for the gather of information regarding human resource practice in construction industry were the personnel from client, consultant and contractors' firms who were involved in the department of human resource management. Scope of data collection was limited to construction organization of Sindh province. Gathered data involved statistical analysis with frequency calculations to draw consensus for determining the practices adopted regarding human resource.

IV. RESULTS AND DISCUSSIONS

In order to understand the practice of human resource management in construction-oriented organizations of Sindh, structured questionnaire was distributed in 15 companies and all the companies were contacted through telephone and by walking in. Only 5 organizations agreed to respond while some of the organizations mentioned that human resource practices are not to disclose while some organizations excused that they are quite busy to participate in survey. Personnel's participating in survey was directly involved in human resource department and had different level of experience of being part in human resource related work. Among these, 2 respondents had experience of 11 to 15 years, while 1 respondent had practiced for a period of below 5 years, 1 respondent was involved in human resource management for a time of 6 to 10 years and 1 respondent had experience for more than 15 years in working with human resource department. The summary of the experience of the respondents is shown in figure 1.

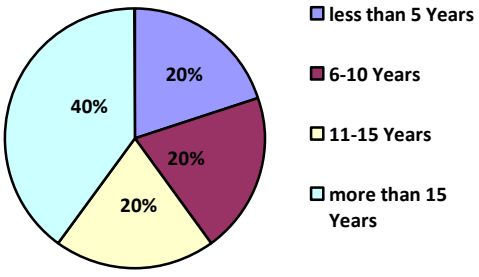

Fig. 5: Experience of respondents participating in survey

As the main objective of this study was the identification of the firms which implement proper human resource management. The respondents were asked the question to know whether that organization adopts proper human resource practices or not. Overall the question focused regarding availability of proper HR department, HRD approach, Implementation level of HRM practices in firm, type of HRM practice in firm, sharing HRM policy document with employee, revision of HRM policy in firm, structure of HRM in firm and adoption of various HRM Models. Summary of the responses received from the participants is presented in table 1.

Table 1: Summary of the responses from Respondents

Q. No	Question	Reply's of Respondents					Frequency
		Respondent 01	Respondent 02	Respondent 03	Respondent 04	Respondent 05	
1.	Organization have Proper HR Department	Yes	Yes	Yes	No	yes	4/5
2	HRD approach in your organization a) HRM Department b) Personnel Management Department c) Human Relation Department d) other(specify)	a)	a)	b)	d) Personnel Information about Integrity & CVs	b)	5/5
3	Mark level of HRM practice implemented in your organization Informal 12 3 4 5 Formal	4	4	1	1	4	5/5
4	HRM Practices adopted in Your Organization a) HRM Policy b) HRM Model c) Other specify	a)	a)	b)	Maximum weight age is given to integrity	a)	5/5
5	Your organization follow National HRM Policy a) Yes b) No c) No Idea	a)	a)	x	b)	b)	4/5
6	HRM policy document shared with the employee at the time of recruiting in firm a) Yes b) No c) No Idea	a)	b)	x	a)	b)	4/5
7	Organization provides the employees the Conditions of Service document on the recruitment? a) Yes b) No c) No Idea	a)	a)	x	a)	a)	4/5
8	How often are these policies revised? And by whom?	N/A	They are revised on need basis can be monthly, quarterly, yearly, accordingly.	Occasionally by the managing partner of the firm	On required basis	x	4/5
9	How HRM department is structured in your organization?	Not idea	Hierarchy based	x	N/A	Self structured	4/5
10	Which HRM model your organization follow? a) The Michigan Model b) The Harvard Framework c) The Guest Model d) The Warwick Model e) No Idea f) Other (please specify)	e) No Idea	x	h) No Idea	Based on personal information obtained through friends & colleagues	x	3/5
11	In your view what is the state of HRM in the construction Industry of Pakistan (Sindh)?	No Idea	x	No Idea	Needs regulation	No Idea	4/5
12	Do you think that there is an immense need of improving HRM practices in construction organization of Pakistan (Sindh)?	x	Yes, in terms of industry benefits	Yes there is an immense need of improving HRM practices in construction organization of Pakistan	Yes, very much	x	3/5

From table 1, it is perceived that 80% of the organization participating in survey mentioned that they have proper human resource department to scrutinize and deploy workforce based on quality and relevancy to the task to be performed. Most of the organizations highlighted that their organization have formal procedures for human resource deployment. However, every organization has their own policy, rule and regulations to deal with human resource related issues. Only one organization indicated that they adopt international HR model. These organizations have proper documentation for the recruitment policy of the staff; however, it was notified that the organization do not have proper schedule for revising and updating human resource policy, but it is performed occasionally when required.

V. CONCLUSION

Human Resource Management plays an effective role in any firm to attain desired targets. This work studies human resource management practices in construction industry of Sindh province. This study revealed that construction organizations are implementing human resource management, but every organization has own set of policies. Based on the findings of this study, it can be concluded that there is need of centralized HR model to implement in all construction organization. This will provide equal opportunities to the entire workforce.

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Structural Stability of Multistory Buildings with Floating Columns

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***Abstract*: Floating columns are the structural compressive members generally taken up from normal sections of resting beam, girder and sometimes from slab which create structural stability problems. Such type of columns are mostly adopted by many local construction industrials without any proper analysis to save some quantity of materials and also sometimes, the client demands the reduction of such columns in order to increase living space as well as saving in construction cost which ultimately puts the structural stability in critical scenario where surety is abated. This research aims at analysis of buildings with floating columns. The main objective of this research is to develop and calculate threaten parameters which are associated with different loading types such as gravitational and seismic loads with different loading intensities over different useable parts of buildings. So, for analysis purpose, a commercial twelve story building which is actually in construction process located in Hyderabad with seismic parameters (Ca = 0.22, Cv = 0.32 and Z = 2A) under soil profile S_D is taken for analysis with structural software ETABS. The methodology employed for this research was to select interior and exterior gird columns, centrally loaded building zones columns and ramp grid columns for parking floors as floating columns. Interpretations were taken from structural parameters including base shear force, overturning moments, lateral displacement, lateral drift, earthquake force in X and Y directions and time analysis was taken separately for building with floating and non-floating columns after which the comparison was made between both types of columns with the help of graphs which ultimately resulted for seismic parameter and recommended many actions which should be taken for structural stability purpose.**

***Keywords*: ETABS, Floating Columns, Seismic Parameters, Structural Parameters.**

I. INTRODUCTION

Since stability of structures is required whether with any sort of loading, any design approach with several limitations (with narrow assumptions) natural hazardous, inevitable local construction methods, and unauthentic assumptions while supposing structural members criteria on own basis, economic considerations of client limited project finances are the challengeable threats for structural engineers to solve or reduce these real field approach problems for the sake of human as well as structure safety.

Many narrow approached structural methods have been adopted in local construction industry of Pakistan to overcome the illegal demands from clients and financial teams to obtain results within their circles without caring about stability out of which few play with grades of materials (Concrete, Steel), poor construction methods while pouring concrete's frame , mason productivity approaches without implementations of standard safety precautions and few play with redundancy in structural member while having approved designs from officials authorities which leads to adaptation of a short come method for structural members known as floating columns.

Floating column as a short come local economy saving method is a structural column which is taken up from resting members of beam, girders, and slabs with normal sections of members due to response of clients demand and economy considerations.

Fig. 1: Red Circle shows Floating Column

II. PROBLEM STATEMENT

Since a common pattern is to transfer the structure's load through columns to foundations in regular or shortest path, structure's stability can be affected if irregular or discontinuous path is adopted to transfer the load to foundation. There will be some uncertainity when we design the structures where load floats in less stiff and less masses floors, thus it will damage the structural members when they are subjected to loads having different instead of regular nature either it could be gravitational loads or lateral loads. Therefore, to meet the stability criteria and reduce load transfer mechanism problems, it becomes necessary to analyze the building with those columns which usually adopt this scenario to structure stability in suspension position

Table 1: Material Properties (Section)

Item	Description
Plan of building	135' x 120'
Building Type	Residential + Commercial
Number of Stories	11 (= 11.625 ft)
Slab Thickness	6 inches
Size of Beam	?? With 3 ksi
Size of Column	?? With 4 Ksi
Live Load on Commercial Floors	80 Psf
Live Load on Residential Floors	40 Psf
Partition Load	20 Psf
Finishes Load	36 Psf
Backfill Load	112 Psf
Coeficients for base shear	Ca = 0.22, Cv = 0.32
Project Seismic Zone	2A
Soil Profile	S_D
Wind Speed	50 MPH with B Exposure Type

III. RESEARCH METHODOLOGY

In order to check the stability of structure with floating columns, structure software ETABS v 9.5 is adopted with Non-Linear static method of analysis. 25 analysis trials have been carried out of which 15 are for exterior gird columns as floating which lie along the outer or exterior girds (1,Q,20 and A) of plans with several trails of corner columns , alternative floor columns , individuals floors from top story to basement story with alternative columns as floating and 10 for interior gird columns as floating which are selected from most dynamic loading girds (19, 16, 3 and G) of ramp , lift elevator and central location of buildings. Similarly, random trials from top story to bottom story from interior girds are selected as floating columns for analysis purpose. The results obtained are then compared for building without floating columns and building with exterior and interior gird floating columns, based on which, results are obtained for base shear force due to Eqx and Eqy , lateral displacement, drift , time of response and overturning moments which are further represented in a graphical format with certain recommendations.

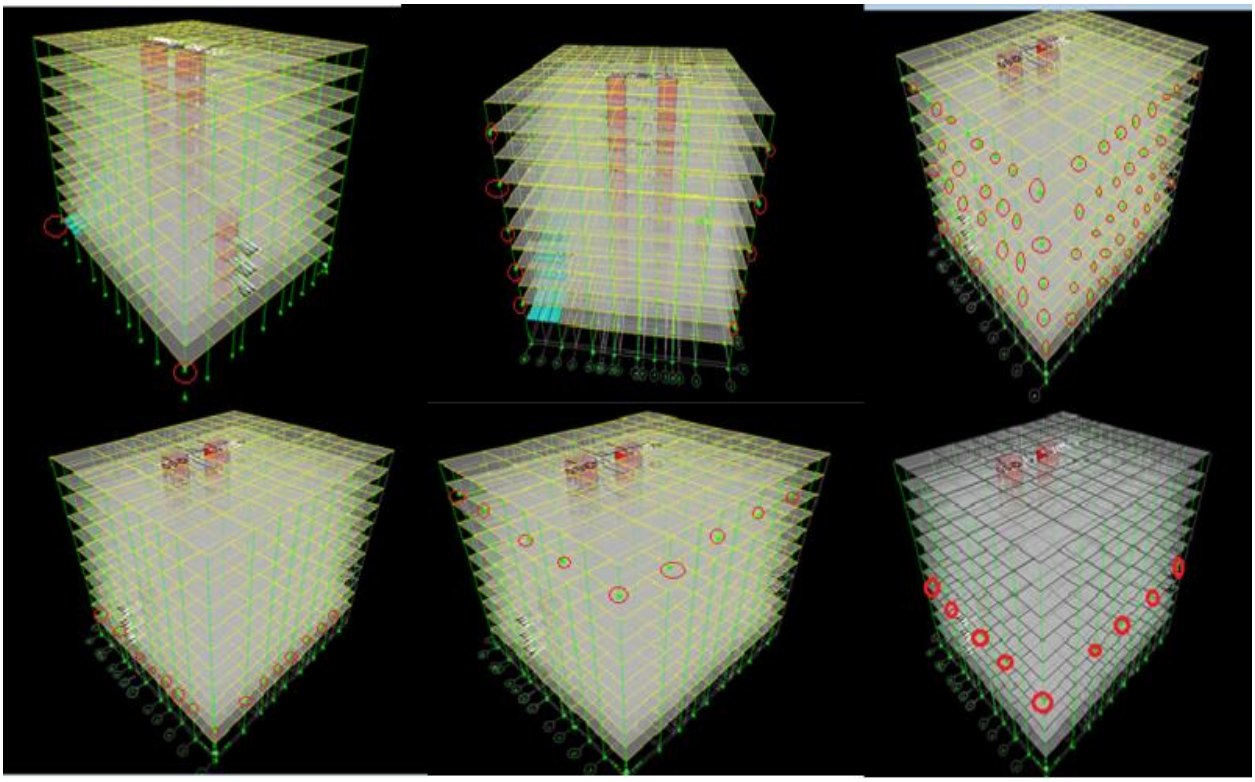

Fig. 2: Red Circles Shows Exterior Flaoting Column trails

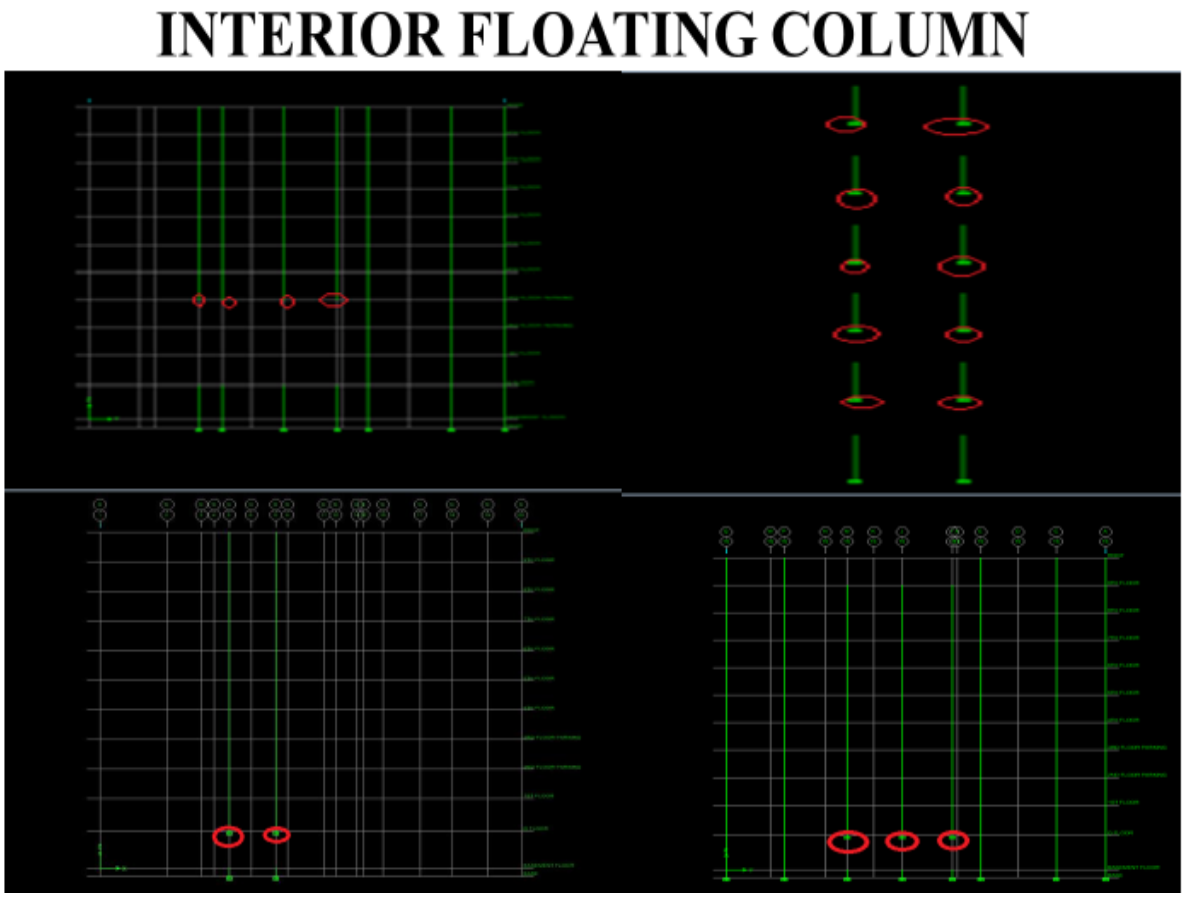

Fig. 3: Red Circles shows Exterior Floating Column trails

IV. Results and Discussion

4.1 Results for Exterior Floating Columns

4.1.1 Base Shear Force

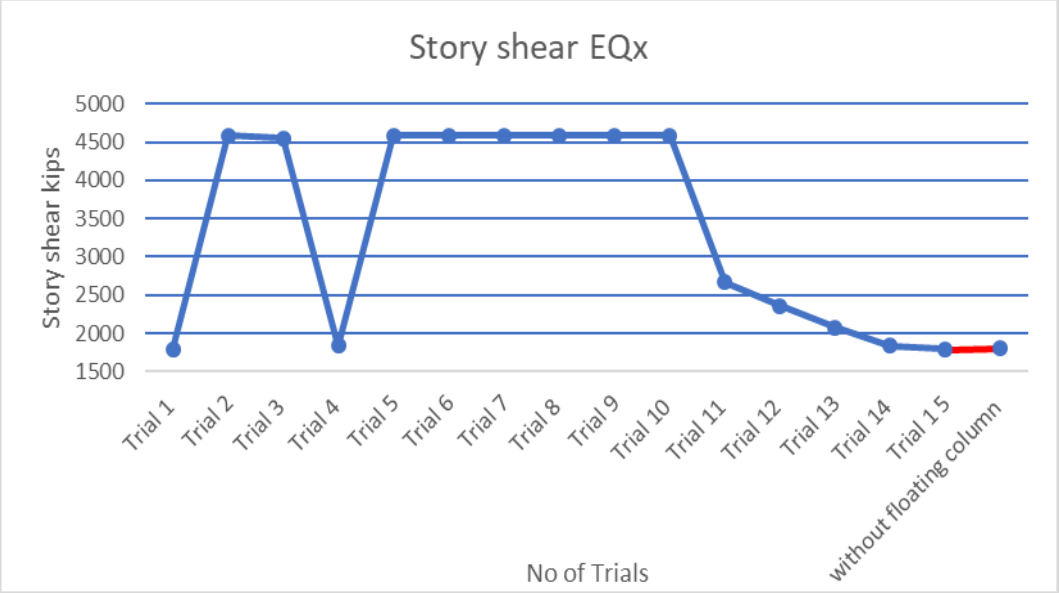

Fig. 4

Figure 4 shows the base shear force for different trials with floating columns. The maximum story shear falls in bottom stories with magnitude of 1795kips with non-floating columns, but its value increases up to 4585kips. Though it somehow falls in middle portion of building at trial no 4 and in bottom stories but mostly its maximum falls in stories of floating columns. Trial No 3 shows the maximum value of base shear force.

4.1.2 Lateral Displacement:

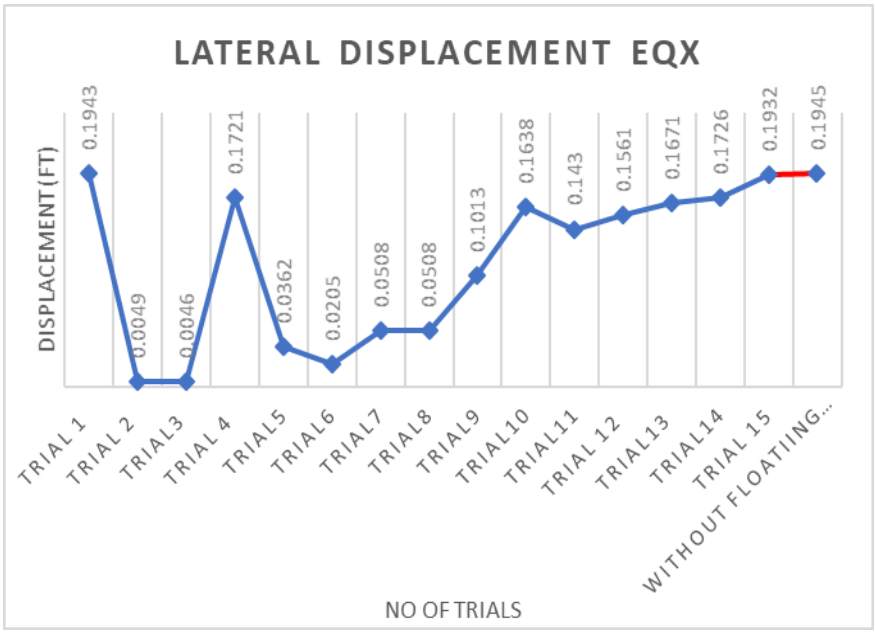

Fig. 5

Figure 5 shows that by introducing floating columns, lateral displacement goes on decreasing which induced high stiffness and low flexibility in building that cause the damage to structures. However, some trials show that by introducing floating column try to increase the displacement, but their values drop below the non-floating columns. Trail no 3 shows the most decreased value of lateral displacement about 0.0046 by introducing floating column.

4.1.2 Lateral Drift

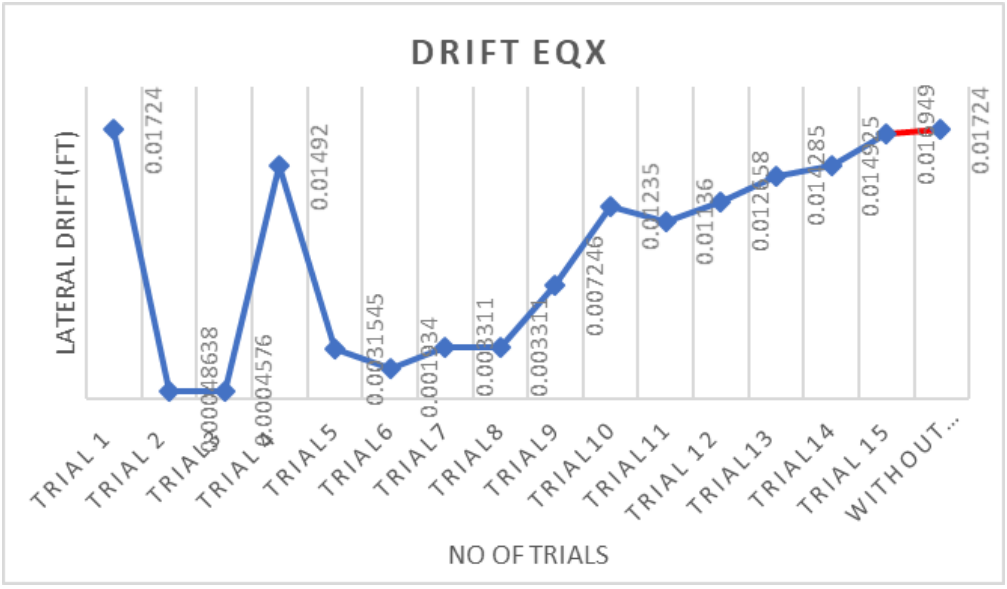

Fig 6

Figure 6 shows that story drift is decreased when we introduce floating columns which allows more stiffness ratio as compared to above or below floor which may cause a building with isolated floors having more stiffness than other floors, ultimately bringing warning areas for structural failures. Trail no 3 shows most decreased value of lateral drift.

4.1.4 Response Time

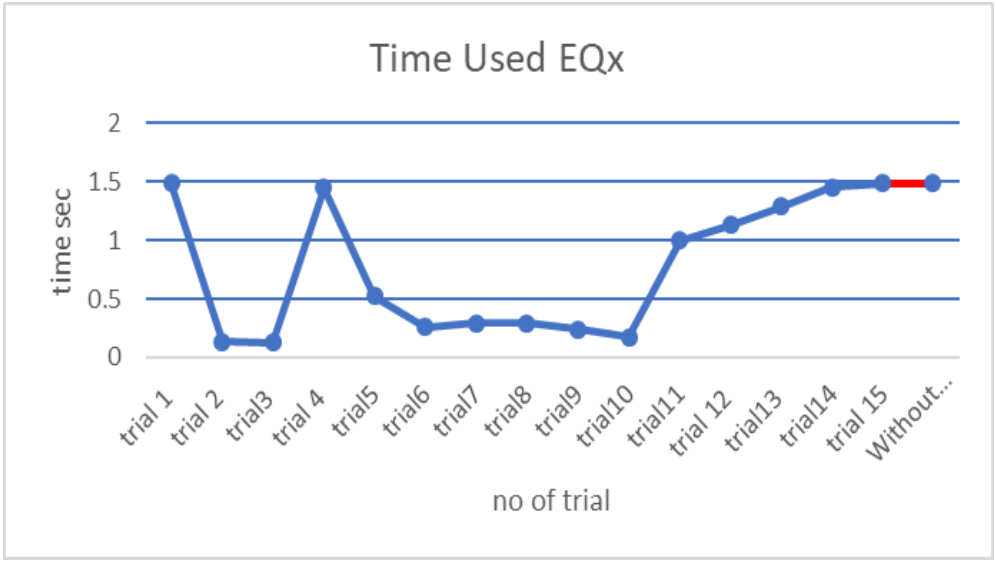

Fig. 7

Figure 7 shows the comparison between response time of building with and without floating columns. Natural response time is 1.4869 sec for buildings with normal columns, but this value goes on decreasing when floating columns are introduced in the building which ultimately results the high stiffness in building or less flexibility providing the constant orientation and size of columns for floating building case.

Since mass of structure is more in case of buildings without floating columns, it proves higher time for building, but this mass gets reduced when we introduced number of floating columns. So, by introducing these, stiffness of structure gets increased which allows less flexibility, so it likely damage more building by providing floating Columns. Trial no 3 shows the most decreased value of response time which gives stiffer floating column building.

4.2 Results for Interior Floating Columns

4.2.1 Base Shear Force

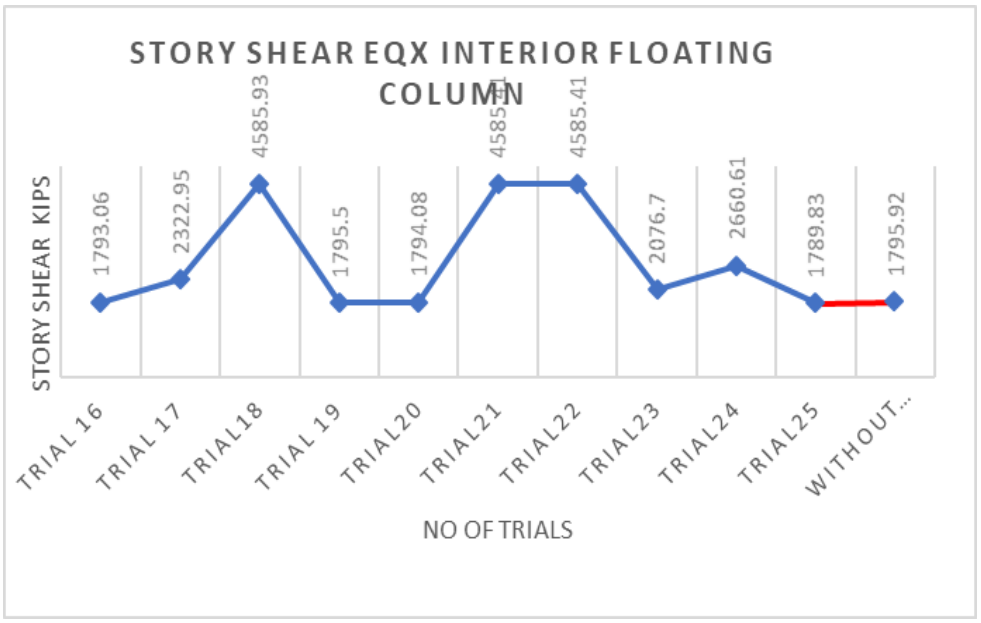

Fig. 8

Figure 8 shows the results of base shear force for interior floating columns whose % variation is almost the same as that of exterior floating trials. Trial No 18 shows maximum value.

4.2.2 Lateral Displacement

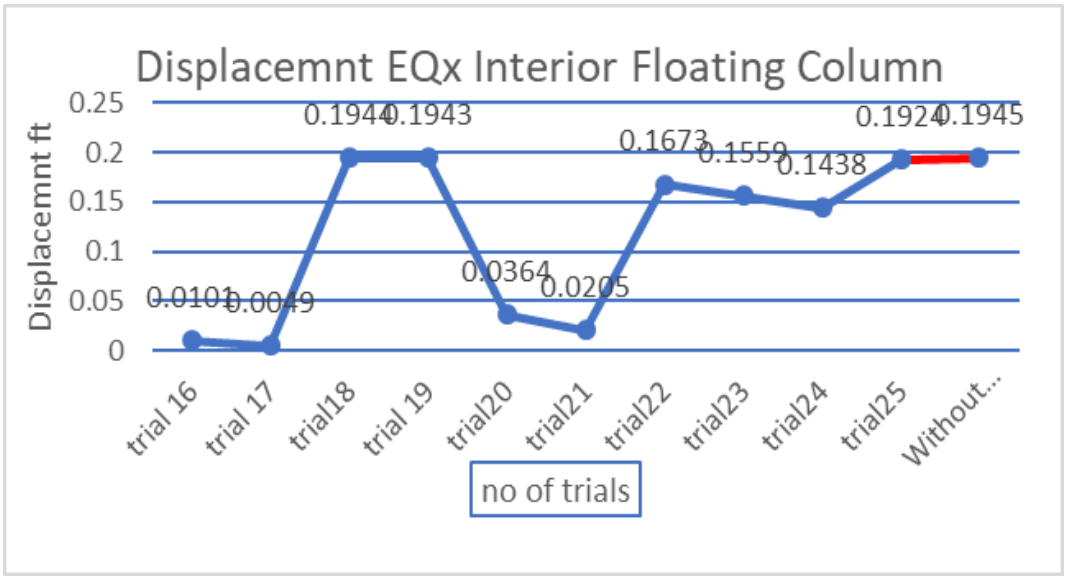

Fig. 9

Figure 9 shows slightly greater value of Lateral Displacement as compared to Exterior Floating Columns for Trail no 17.

4.2.3 Lateral Drift

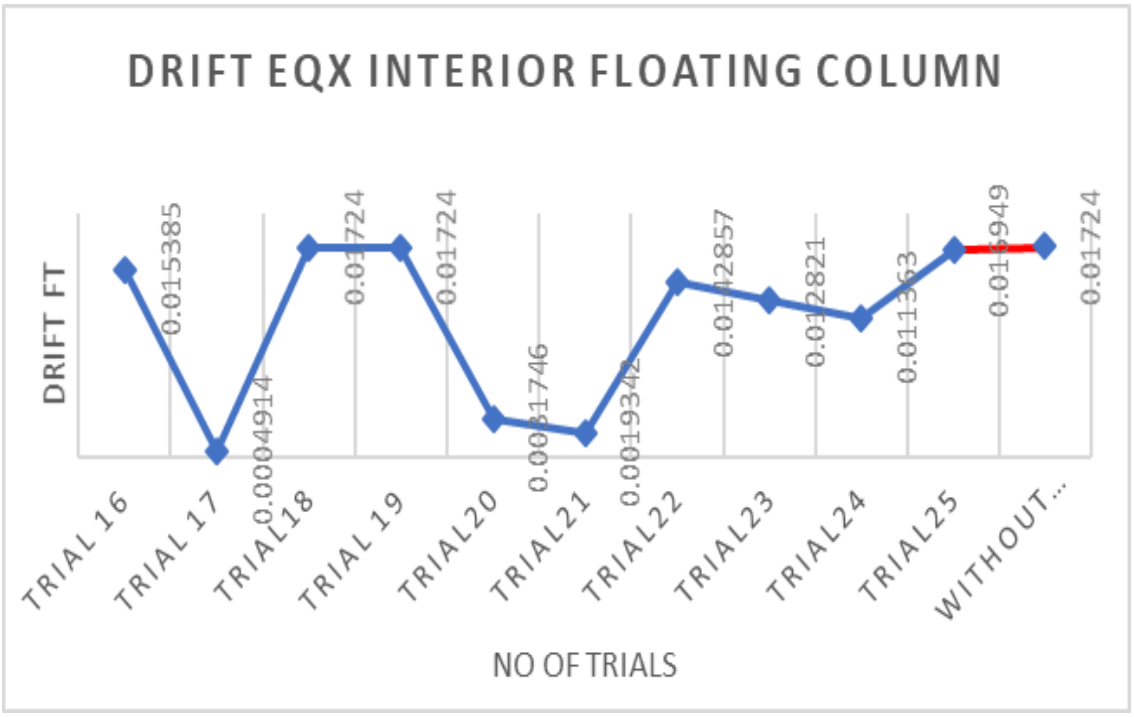

Fig. 10

Figure 10 shows that the drift of interior floating column is slightly less than the exterior floating columns. Trail no 17 shows maximum drift value.

4.2.4 Response Time

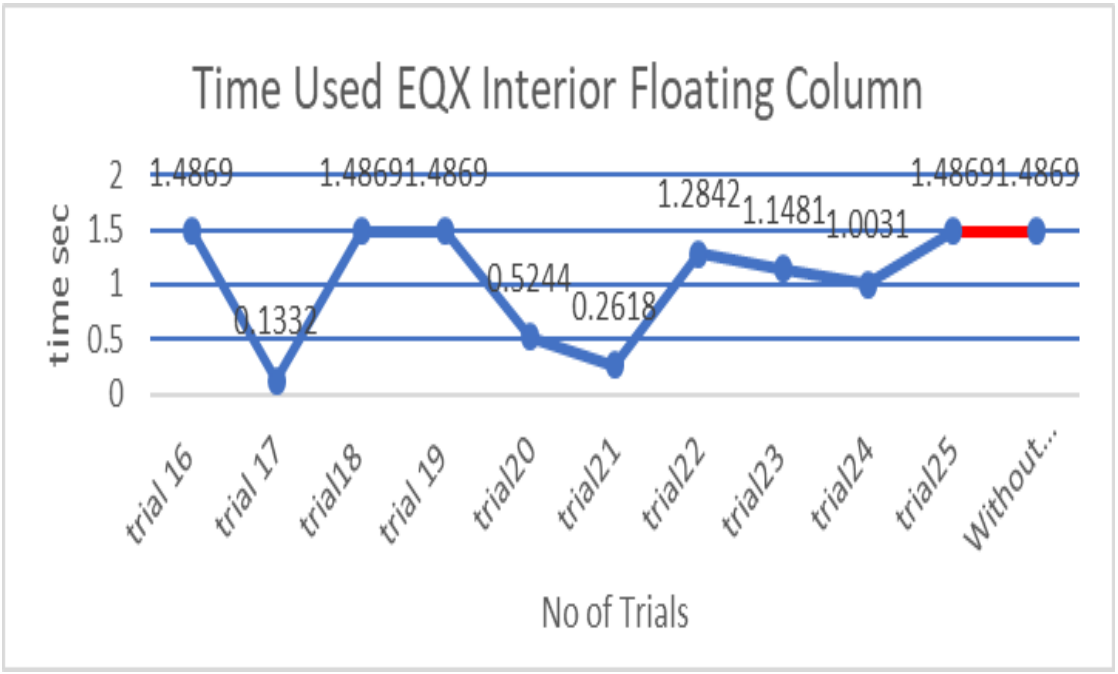

Fig. 11

Figure 11 shows the response time for interior floating columns. Response time is almost same for exterior and interior floating buildings. Trail no 17 shows its maximum value.

4.3 Graphical Representation of Variation in Seismic Parameters with Non- Floating Column Building

Figure 13a shows that building without floating columns whose base shear gradually increases from top story to bottom story, has maximum base shear value in bottom floors of buildings. The lateral displacement of storey (Fig 13b) increases with some degree of linearity along the heights of floors with its maximum value resting on top storey whereas its lateral displacement is almost zero in bottom floors because of lateral stability. Lateral Drift Value (Fig 13c) initially increases then gets reverse turn in curve for middle stories with humps in curve but it tends to increase for topmost stories where its maximum value lies. Fig 13d shows overturning moments which show regular behavior with some linear degree curve whose value gradually increases from top floors to bottom floors whereas it has maximum value in bottom floors.

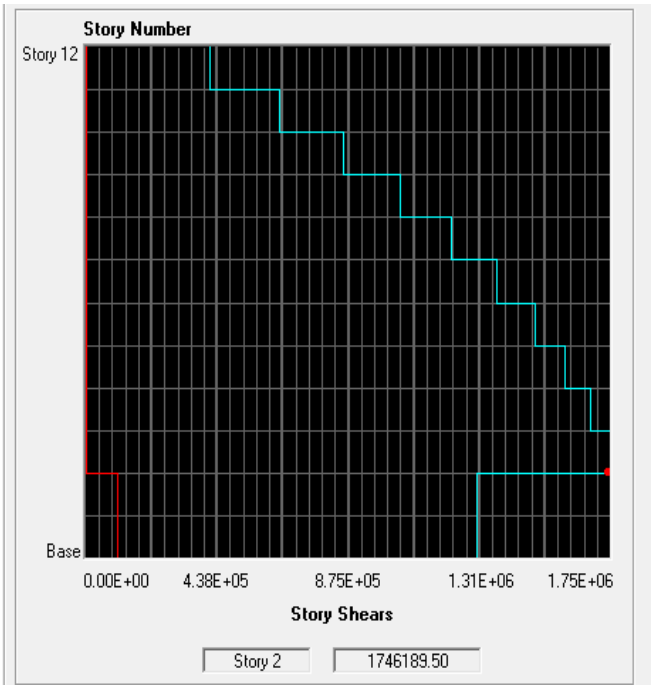

Fig. 13 a

Fig. 13 b

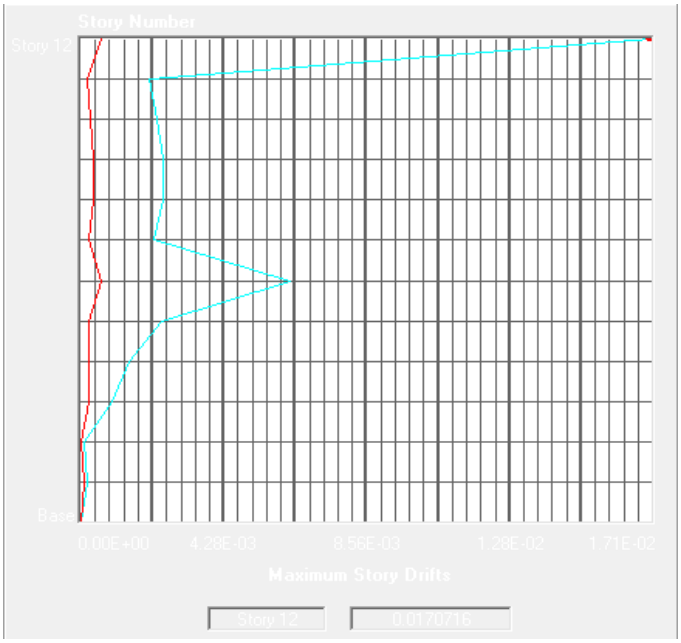

Fig 13 c:

Fig 13 d:

4.3 Graphical Representation of Variation in Seismic Parameters with Floating Column Building

Figure 14 (a, b, c, d) show that by introducing floating columns in building, almost every parameter changes its behavior from regular i.e without Floating. The base shear changes its position and rest its maximum value where floating columns are provided (Fig 14a). Drift (Fig 14b) shows maximum value in floors where floating columns are provided with certain high magnitude in bottom and middle floors. Fig 14c shows lateral displacement which follows inverted dump curves with high magnitude in floors of floating column with variable location. Overturning moments show irregular behavior with two or more maximum for single trial. It follows almost zigzag curve with change of magnitude and location which ultimately brings threats for structural stability (Fig 14d).

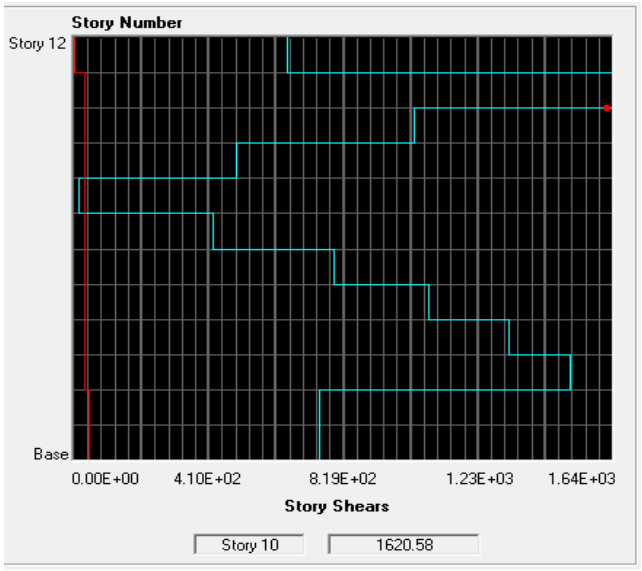

Fig. 14 a

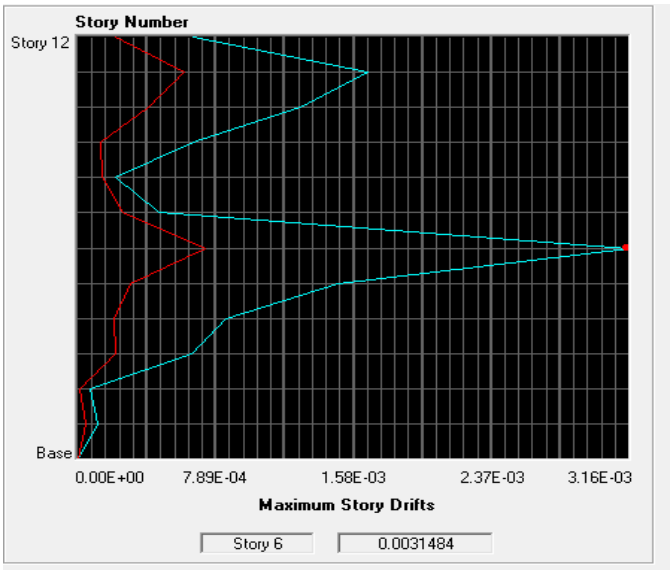

Fig. 14 b

Fig. 14 c

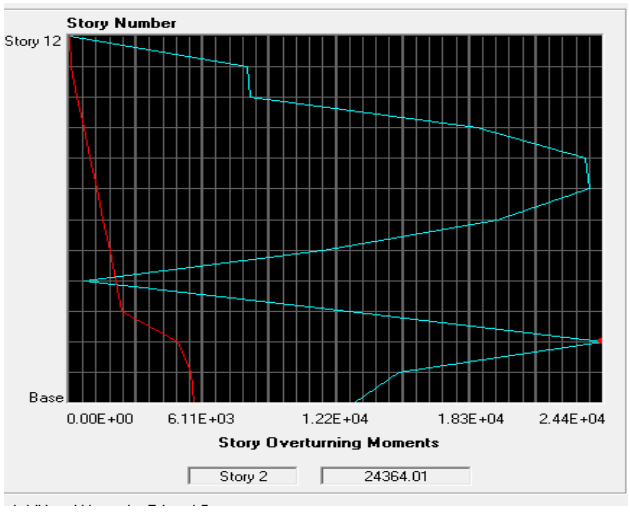

Fig. 14 d

V. CONCLUSION

From the results of research. Following conclusions are drawn separately for both floating and non-floating column buildings

1. Story Shear is maximum in bottom stories
2. Drift initially increases from bottom stories but decreases in middle floors and it shows maximum value on topmost floor.
3. Lateral Displacement increases with some degree of linearity along the height of floors and it has maximum value at topmost floor.
4. From story response graph, it is observed that Ground floor is mostly affected from overturning moments because of all loads may be transferred along this floor whereas moments get decreases along the height of floors.

5.2 With Floating Columns

1. Story shear increases in the floors where floating columns are provided, its value increases more than 60% for both interior and exterior floating columns. Hence, floating column weakens the structure to sustain lateral loads which is likely to cause more damage as compared to non-floating column buildings.
2. Lateral Displacement tends to increase in floors of floating column building with gap straight curve which shows the signs that more the floating columns in single floor, more will be displacement but that is less than non-floating column buildings. Upto 90% value decreases as compared of non-floating building which ultimately results in more stiffness.
3. Drift increases with inclined line in floating column floors whereas it shows straight variation in non-floating column. Hence, the drift curve has more slope value with floating column. Upto 90% Value decreases as compared to non-floating building columns which ultimately results in more stiffness.
4. Overturning moments shows irregular behavior since their value increases in floating column floors but decreases or sometimes increases in non-floating column floors. They follow Zigzag curve, semi parabolic curve and Inverted Dump bell curve which shows the irregularity distribution of moments along the floors. Hence, this variation may be dangerous particularly if any floor occupies over the change point moment curve which results in damage to individual floor.
5. Time of Response is reduced in case of floating Columns because the mass of structure is reduced, and stiffness is increased. Thus, the ability of structure to sustain earthquake waves is decreased.
6. Since by providing floating columns, buildings stiffness increases which allows less flexibility and less time required to complete natural oscillation, it brings more damage to Structures.

VI. RECOMMENDATIONS

1. Do not provide floating columns in building because story shear increases upto maximum magnitude for floors having these columns.
2. In case of floors having floating columns, story shear damages the structure and reduces the earthquake force bearing capacity of that floor therefore, it will be better to avoid these columns in Construction.
3. Buildings with floating columns will take less time to collapse because the mass of structure is decreased while in non-floating case, more mass of structure can sustain earthquake waves.
4. Floating columns are not recommended for small height buildings having 1 to 10 stories because they reduce the flexibility and response time of the structures.
5. It is better to avoid floating column from slab normal section, otherwise cone depression bending will be produced around perimeter of that column which will cause serious damage.
6. Finite modeling analysis and stress analysis of these columns must be made with different cases of supports, material properties, different earthquake zone intensities and a clear code provision must be published whether to use these columns or not.
7. Floating columns are seriously affected by earthquake due to high torsional moments therefore, it would be better not to use these columns.
8. Do not use such columns in case of residential buildings as it will create fear in minds of residents about the collapse of building at any stage. Instead, protect resident life with safe Structural Designs
9. Moreover, overturning moments show irregular behavior which cause serious damage over the change point of moments magnitude which results failure of individual floors.
10. Since this is Risk Based Design of Floating column which has high uncertainty of failure so this may not be reliable design hence inadequate for Real Construction.
11. Initially, building with floating columns is economical because it involves a smaller number of columns but highly dangerous that could end Human life and capitals invested in building.

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Deployment of Greywater Reuse Systems in Residential Buildings

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***Abstract*: The adoption of water conservation measures in urban areas is a fundamental practice to guarantee the sustainable development of society. Among the various conservation measures, the implementation of greywater reuse systems in residential buildings for non-potable uses is a particularly interesting practice because of the already applied technology in conventional sewage treatment, recognized as being efficient. However, for the implementation to happen in a harmonic way, a detailed study on the interface of the treatment systems to the building systems is necessary, as well as an efficient interaction with the architecture and the structure of the building, guaranteeing conditions to implantation, operation and maintenance of the reuse systems. This paper presents application characteristics of greywater reuse systems in residential buildings, as well as some of the main aspects involved between building design and reuse systems. The analysis and compatibilization of projects designed to three different projects of a construction company allowed to write a list of recommendations to be observed in the design phase, in order to guarantee adequate conditions to the implementation, operation and maintenance of reuse systems.**

***Keywords*: Greywater, reuse, building systems, sustainable buildings**

I. INTRODUCTION

The necessity of conservation of potable water is a global requirement, reaching countries with high water availability, as,

for instance, Brazil. According to a heterogeneous demographic distribution, the national regions with lower availability of potable water are the most populated areas, as, for example, the southeast region. It is also in this area that most part of the urban centers are located, for example São Paulo and Rio de Janeiro, and in these places, the portion of residential water consumption is substantial. Therefore, it is necessary to elaborate some measures that allow the reuse of water, improving the interest of the population regarding the reuse of greywater.

Water derived from domestic usage, produced by showers, sinks and washing machines is denominated greywater. According to the presence of oil and fat, some authors do not consider as greywater the effluent originated from sinks, framing this effluent in the category of blackwater [1]. In the case of residential buildings, the reuse of greywater is the most recommended, as this water presents a higher quality when compared to conventional sewage water. Greywater is efficient regarding its reuse, as it presents constant availability over the time, lower concentration of nutrients and lower quantity of organic compounds, when compared to sewage water, and it is easy to be degraded [2].

An average of 40% of the water consumed in Brazilian residences is used in non-potable contexts, as toilet flushes, floor washing, irrigation systems and others [1]. Analogously, the consumption of reuse water to these assets contributes to the maintenance of potable water where its quality is indispensable. Furthermore, this may be an excellent practice considering the environmental aspect, as it contributes with the decrease of water withdrawal and with the emission of effluents to the sewage system [3].

The reuse of greywater considers the necessity of treatment of raw effluents, as the final physical, chemical and biological characteristics must be appropriate to the purpose of usage of this water [4]. According to this concept, the greywater treatment stations are facilities implemented inside buildings with the main objective of returning to the consumer an adequate effluent to internal non-potable usage, as an odor free, not presenting health risks and aesthetically acceptable water.

Countries as Germany, Australia, Japan and the United States of America present internal regulations regarding the reuse of greywater to a non-potable usage. In Brazil, on the other hand, technical rules aiming greywater treatment stations are not present, although technical literature establishes some patterns regarding the reuse of water in non-potable situations. The part 1 of NBR 15575/13 quotes that "water derived from hydro-sanitary facilities must be referred to the public network system of collection" [5], but the same rule recommends the adoption of actions that aim to minimize the water consumption and enable the reuse, providing a guideline to the deployment of reuse systems in current installation processes.

This article aims to present guidelines to the deployment of greywater reuse systems in residential buildings and the relation between these systems and the building interface, in order to ensure appropriate conditions to installation, procedure and maintenance of the systems.

II. METHOD

An analysis was performed considering three projects designed by three distinct enterprises in the city of Sao Paulo. The study was developed as an interdisciplinary activity, aiming to identify two distinct stations, still on design stage, with potential to the treatment of greywater, in addition, it aimed to identify which characteristics a building is supposed to present in order to successfully implement the reuse system. The analysis was conducted following the principles below:

- Identification of two greywater treatment stations to be applied in buildings;
- Evaluation of the necessary alterations on the architecture projects and on the building systems for the deployment of the reuse systems;
- Preparation of a list of recommendations to be applied on the evaluation and acceptance of reuse systems projects, based on implementation aspects, operation and maintenance of this kind of system.

III. CHARACTERIZATION OF THE SYSTEM

a. Reuse of greywater: application on residential buildings

The greywater is separately gathered from the sewage and taken to internal treatment stations, where, through filters, biological processes and disinfection, the quality of the water is modified, reaching acceptable patterns to the non-potable use. The water is treated and distributed by independent networks to be used on toilet flushes, washbasins, floor cleaning, irrigation systems and others. Thus, the system requires a distinct pipe to collect the water and distribute it as reuse water. Figure 1 presents a conventional greywater reuse system.

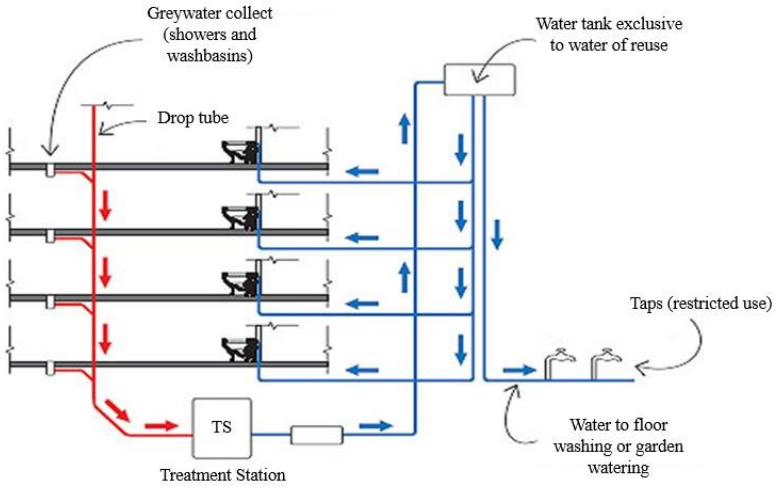

Fig. 1: Deployment of a greywater reuse system in buildings

The technological advance in the processes of sewage treatment allows the establishment of compact reactors, efficient to the treatment of greywater directly from the building. This equipment is available on the market. Among the reactors applied in the country, there is the Biodisc reactor, Submerged Aerated Biological Filter, Compartmentalized Anaerobic Reactor, Moving Bed Biofilm Reactor, in addition to the advanced treatment plants with filter membrane and reactors based on chemical coagulation and flocculation. The technological selection of the reactor must be adequate to the level of treatment required by the reuse water. This level is variable according to the degree of contact of the consumer with the treated water. It is substantial to the success of the project that the relation between cost and benefit obtained with the deployment of the treatment station is the best possible.

b. Greywater treatment stations: selection criterion

To the selection of the treatment station, the following requirements were adopted by the construction company:

- The area to be provided to the implementation of the treatment station must be the smallest possible;
- The treatment station must provide reuse water to be used in toilet flushes, floor cleaning and irrigation systems, according to the quality parameter pre-established by the national standard.
- The treatment station must present the stages of decantation, biological treatment, filtration and disinfection with sodium hypochlorite;

- The operation cost of the treatment system must be the smallest possible, stimulating the acceptance of the system by the final user. According to the current high cost of the operation, treatment facilities with filter membrane has been avoided;
- The companies responsible for the selling and installation of the treatment stations must provide services of operation, maintenance and replacement of input to the condominium, in addition to perform the periodic analysis on the quality of the water.

The requirements conducted to the selection of two different treatment stations with potential to achieve the same level of treatment: treatment with biodiscs and MBBR (Moving Bed Biofilm Reactor). The hydraulic flow for both stations is shown on Figure 2.

Fig. 2: Hydraulic flow in treatment stations

c. Necessary characteristics to implement reuse systems in a building

The topics bellow represents the conditions that a building must present to the implementation of reuse systems, focusing on the installation area, maintenance conditions, disclosing of spaces in shafts and the relation with building systems.

Choosing the area to install the greywater treatment station

The choice of the area to install the treatment station in a building must consider operation conditions and maintenance of the system. In order to choose the appropriate location, the architect must consider the following scenario:

- Necessity of frequent monitoring of the effluent in the treatment station;
- Possibility of odor production in the biological stage of the treatment;
- Production of noise due to the functioning of pumps and engines;
- Entry of raw greywater 24 hours/ day, with the flow varying according to the peak time;
- Production of concentrated load over the building, at the points of accumulation, treatment and reservation of water;
- Operations regarding the removal and manipulation of sludge;
- Leakage and cleaning maintenance of the system;
- Circulation of people and equipment;
- Storage and manipulation of chemical products.

Provision of spaces for shafts

For being a totally isolated and independent system, the reuse water collection and distribution network requires a specific area to be implemented. The greywater collection shafts may be the same utilized for the passage of columns of sewage collection and ventilation of the sewage building systems, in the interior of autonomous unities. A difficulty regards the decrease on the size of bathrooms. According to Pastrello (2014), in the last 30 years, there was a decrease of 35% on the area of this facility, reflecting on the reduction of the space for installations and hydraulics connections, decreasing the comfort on the execution of the service by the installer. It is important to observe that the demanded space for the pipes of the reuse systems in these shafts may be bigger than the necessary in a conventional system, as the quantity of pipes is increased. On the contrary to what should be the ideal, the dimensions of the shafts are bound to the layout of the environment in which it is located, and not to the quantity of pipes that they cover, and normally they are defined by the architect and not by the building systems designer. For that matter, the interaction between designer and architect is substantial for the implementation of the system.

Relations with the buildings sewage systems

The definition of the greywater collection points must occur after the study on the compatibility between supply and demand. After the definition of the points, the discharge and sewage extensions, ventilation extensions, drop tubes and ventilation columns are rated. The rating of each subsystem may be performed by the Hunter Unities of Contribution (UHC), as this is the most utilized method. Considering the reuse process, the particularity consists in the allocation of the collected effluent, as the detachment of the sewage into specific extension lines and drop tubes is required. In bathrooms, for example, it is important to utilize a drop tube for the sanitary exhaustion of black water, and another one to collect the greywater. The black water is directed to the local collection network, and the greywater is directed to the entrance of the treatment station. Regarding the collection of washing machines water, it is necessary to be careful. Normally, the same drop tube is utilized in a project for the collection of washing machine water and sink water, and as the sewage from the sinks is not adequate to be

reused, it is recommended to individualize this allocation. All cautions regarding the overpressure zones, column siphoning and protection against retro siphoning must be considered.

Concerning the distribution of reuse water, the sizing of the pipes must be achieved with the same criteria applied in order to measure the sizing of the potable water network. It is also important to notice that the pumps utilized in the repression of the reuse water, for the pressurization of the water in the superior floors and the pressure reducing valves in the inferior floors, may be the same as the ones used in the distribution of potable cold water. The levels of chlorine present in the reuse water are not considered to be dangerous for this equipment, as this level is limited to 2 mg/ 1.

IV. RECCOMENDATIONS TO IMPLEMENT GREYWATER REUSE SYSTEMS IN BUILDINGS

Considering the analysis of developed projects and actions applied aiming their improvement, the authors have created a set of recommendations that may be used to the design of reuse systems. The proposals are presented on Pictures 1, 2 and 3.

Frame 1 – Recommendations regarding the *Greywater treatment station* Project.

• Perform the hydric balance considering the sizing of the greywater treatment station; • Ensure the application of primary equalization tanks for every treatment system selected; • Evaluate the viability of incorporation of anaerobic systems (optional) anteceding the aerobic stage, decreasing operation costs; • The aerobic treatment stage is necessary to obtain adequate levels of treatment; • Evaluate the possibility of incorporation of advanced treatment stages in the treatment stations (filter membrane, for example), considering applications that require a higher level of treatment; • Apply secondary decantation tanks in sludge generating systems; • The disinfection stage (chlorine or derivatives, ozone or ultraviolet) is mandatory; • Ensure, in the project stage, the possibility of recirculation of decanted sludge to the initial stage of the process (if the increase of the treatment during the operation is necessary); • Provide conditions for the eventual expansion of the treatment system, considering cases in which it is necessary to readjust the operational system; • Every reservoir must present a drainage mechanism for cleaning, and extra flow pipe; • The treatment station project must describe the levels of activation and deactivation of every component (pumps, level sensor, solenoid valve, etc.);	• Predict a holding tank of 30 minutes minimum, assuring the disinfection efficiency; • The treatment station must include a reservoir for the treated water. It is necessary to evaluate the necessity of complementation of potable water in this reservoir. If there are superior treated water reservoirs, the complementation must be performed in the superior reservoirs, as they are the last supply point before the distribution. This measure avoids unnecessary potable water complementation; • The treatment station must include a faucet with a padlock, in order to enable the collection of samples after de disinfection stage; • It is recommended that the treatment stations possess manometer, in order to verify the network pressure; • The project must present the treatment flowchart with the quotas of the hydraulic profile; • It is recommended to add blue dye in the treatment stage, in order to visually differ the potable and non-potable water; • The Project of the treatment station must inform all the weight of the components; • In case of utilizing, in the third stage, a filter that must be continually cleaned (sand filter, for example), the project must predict the utilization of water derived from the treatment station to perform the cleaning processes. It is recommended to automate this stage with the usage of the timer on the command panel; • Every pump from the treatment station must be protected by the usage of level sensors, in order to stop the operation of the pumps if the reservoir is empty, through the configuration on the command panel.

Frame 2 – Recommendations regarding the *Architecture* project.

• Position the treatment station distant from recreation areas; • Ensure access conditions to the components in the entrance of the treatment station; • Predict natural or mechanical extraction ventilation inside the treatment station; • Predict mechanical ventilated doors, if possible, with double opening (free space of 2,00m), or removable metallic mesh; • Predict access to removal/ substitution of components and reservoirs during the operation of the system in the building;	• Provide enough area in the shafts related to the greywater collection network, and validate the dimensions of the shafts with the designer of the building sewage projects; • Verify with the designer of the building projects the necessary places to install the pressure reducer (installation in shafts in the pavement or underground); • Orientate the identification of the points of utilization of reuse water with visual communication boards.

Frame 3 – Recommendations regarding the *Building Systems* project

• Dimension the collection extension lines, drop tubes, collectors and greywater ventilation columns by the Hunter Unities of Contribution; • Avoid collection of greywaters from washing tanks and sinks; • If the collection of water prevenient from washing machines is required, verify if the extension line is separated from the washing tank extension line; • To sludge and solid material conductors from the treatment station reservoir, dimension the sewage conducting tubes with the Hunter Unities of Contribution used for sanitary vases; • Predict containment box for the collection of the extra flow effluent and drains of the treatment station; • Predict siphoning in the network passage boxes; • Do not utilize floor drain with siphoned box as a method of capitation in containment boxes, considering the presence of solid materials in the system; • Indicate the collected raw greywater to the entrance of the treatment station; • Predict floor drain in the destined environment of the treatment station, in order to wash the floor; • Dimension and detail the repression system, pressurization and distribution of the reuse water; • Specify repression and pressurization pumps, that may be the same as the ones utilized for the repression of potable water; • Dimension and detail the pressure reducer station of non-potable water. The valves may be the same as the ones utilized for potable water;	• Verify the applicability of filter in the distribution system of non-potable water, to be installed at the exit of the keg, in order to protect the pressure reducing valve, minimizing maintenance processes; • Detail the central shaft of non-potable water distribution; • Avoid cross connection (between potable and non-potable water); • Ensure protection against retro siphoning in the reservoirs and appliances supplied with non-potable water; • Ensure the complementation of the system with potable water for emergency situations; • Predict infrastructure to individualize the measure of consumption of non-potable water; • Specify faucets with padlocks for the points of application of reuse water; • Direct the project (scenario and detailing), the colors to paint the pipe in the shafts, underground roofs or other areas with visible pipes; • Enable electric charge to supply the command panel of the treatment station. The output must be provided by the supplier of the greywater treatment system; • Dimension the circuit of supply of the treatment station command panel; • Predict electrical charge to supply the pumps and pressurizers related to the distribution system of non-potable water, presented by the project of hydraulic facilities. • Detail in the command panel the components related to the activation of pumps and pressurizers;

V. CONCLUSIONS

The implementation of greywater reuse systems in residential buildings is a reality around the world, and it is gradually achieving its space in Brazil. The technological advance of the market in the development of compact and efficient treatment stations has been benefitting its operation in buildings. This process is increasingly being incorporated on projects of current building systems. The perspective of economy of potable water in residential buildings with the implementation of greywater reuse systems is of about 40% of the total volume.

The choice to collect greywater is interesting because it presents a constant availability, in contrast to what happens in systems that utilize pluvial water. However, despite greywater presents a smaller organic charge when compared to the conventional sewage, its usage must be carefully planned, aiming to avoid health risks to the consumers. Thus, it is important that the effluent derived from the treatment station satisfies the physical, chemical and microbiological pre-established parameters, in order to be available to be used, even for non-potable situations.

In the project design stage, it is substantial to ensure the adequacy of the intended application of the water, reflecting on the level of treatment that is necessary, in addition to the deployment and operation costs, so the deployment of the reuse systems may be effectively enabled. Although there is not a Brazilian technical standard that may guide the composition and the basic stages of a treatment station for this purpose, some considerations are substantial, as the presence of a biological stage in order to convert organic material; aerobic stage to remove turbidity, the possibility of sludge recirculation and expansion of the system in an operational stage, the analysis of applicability of advanced treatment systems (filter membrane, for example) in contexts that require a higher level of treatment, the presence of a third stage to filter solid material and improve the visual aspect of the water, and a disinfection stage, efficient to eliminate pathogenic agents, performed by the addition of dye, ozonization or application of ultraviolet radiation.

VI. RECOMMENDATIONS

Although the critical analysis performed during the planning stage enables to help and improve the projects related to reuse systems, it is recommended to develop a field evaluation of the real performance of the treatment stations in buildings in the operational stage, aiming to identify restrictions and opportunities to improve the system and give a feedback to all designers engaged in the elaboration of this kind of procedure.

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Empirical Effect of Different Hydraulic Retention Time Levels on the Removal of BOD & COD Through RBC

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***Abstract*: Paired t-test is a special technique called randomized block design provides the method for comparing two population means. This procedure determines the probability distribution of the random variable. In the present study paired t-test is used to compare the population means of the Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) taken from Rotating Biological Contactor (RBC) at different Hydraulic Retention Time (HRTs) i.e. 2 hours (0.42 l/min), 2.5 hours (0.33 l/min) and 3 hours (0.28 l/min) respectively with 9.78 m^2 discs surface area. The Box plots and mean values revealed that the removal % of BOD5 is much better than the removal % of COD at all HRTs. Study revealed that RBC is much affected technique for removal of BOD5 than COD. Computed values of paired t- test statistic are 6.61, 5.83 and 15.98 and all these three t-value are > the $t_{\alpha/2,n-1} = 2.262$, that's why reject all three null hypothesis H0.corresponding p-values are less than even 0.01, while level of significance was 0.05, as it is a sufficient evidence to indicate that the removal % at all HRTs is not same.**

***Keyword*: Paired t- test, Biological Oxygen Demand, Chemical Oxygen Demand, Hydraulic Retention Time, Rotating Biological Contactor.**

I. INTRODUCTION

The significance of fresh water at all, can never be denied and the freshwater assets are under great pressure particularly in the crowded countries. Pakistan possesses eighth rank along with the major water consumer countries of the global water assets. Hoekstra et al (2007) delineated that, such populous countries jointly contribute fifty percent to the total global water footprint. Asian Development Bank Report (2013) affirmed that, throughout the world Pakistan also one of the large amount water-stressed countries. In all regions of the world shortages are revealed, for the duration of last 20 years in per capita turn down of existing water (Gleick 2003). Fresh water accessibility has decreased in Pakistan per capita for each year from 5600 to 1000 m^3 in last six decades and it could go down supplementary in the future years to the level underneath 1000 m^3 per capita for each year as this point is considered as water scarce level (Sheikh et al 2005).

A country is supposed to be harassed when water provisions go down below 1000 cubic meters per person per year as demonstrated by Falkenmark and Lindh (1976). Recycling of wastewater is one of the probable alternatives, according to such facts, to get to the metropolitan water stress and as well as up to some level to meet the irrigation needs. It has become essential to treat and recycle the used water, to decrease utilization of ground and exterior water, mutually with other water saving procedures. Significantly these techniques may reduce as well as contribute the demands on freshwater resources (Pathan, A. A et al 2015). Kadu & Rao (2012) stated that Rotating Biological Contactor (RBC) tool characteristically includes of a sequence of closely gaped big plane or ridged discs that are accumulated on a common horizontal shaft and are incompletely immersed in wastewater.

The paired t- test is one sample t- test simply, with null hypothesis $H_0 = 0$, applied to a population of paired differences. The procedure of t -test was introduced by William Gosset in 1908 which establishes the probability distribution of the random variable. As probabilities for a random variable having a normal distribution are equal to areas under normal curve, the same way probabilities of a random variable having t – distribution are also equal to the area under t- curve (Weiss N.A 2017). Basic assumptions of using t- distribution are, the sample of n observations X_1, X_2, X_3,……,X_n taken from population selected randomly, population from which small sample (<30) is drawn should be normal and in case of two small samples, both samples are selected randomly, population should be normal and having equal variances (chaudhry, S. M., and S. kamal (2012). Paired comparison design illustrates the blocking principle which is a particular problem of more general type of design called the randomized block design. Test statistic is a calculated quantity of the sample used when making a decision regarding the hypothesis of interest. Numerical values of the test statistic for which null hypothesis is rejected are known as rejection or critical region of the test (Syed khursheed Alam 2013).

Henry Hsu et al (2008) stated that this technique is utilized to evaluate average variations among treatments when the surveillances have been acquired in a couples or pairs. Expectations are zero, the null hypothesis that is tested by Student's *t* test and the difference between the paired values is supposed to be normally distributed.

The paired t- test with null hypothesis $H_0 = 0$, applied to a population of paired differences to find out the differences of the mean values of Biological Oxygen Demand and Chemical Oxygen Demand from Rotating Biological Contactor with one contribution factor i.e. Hydraulic Retention Time.

II. HYPOTHESIS

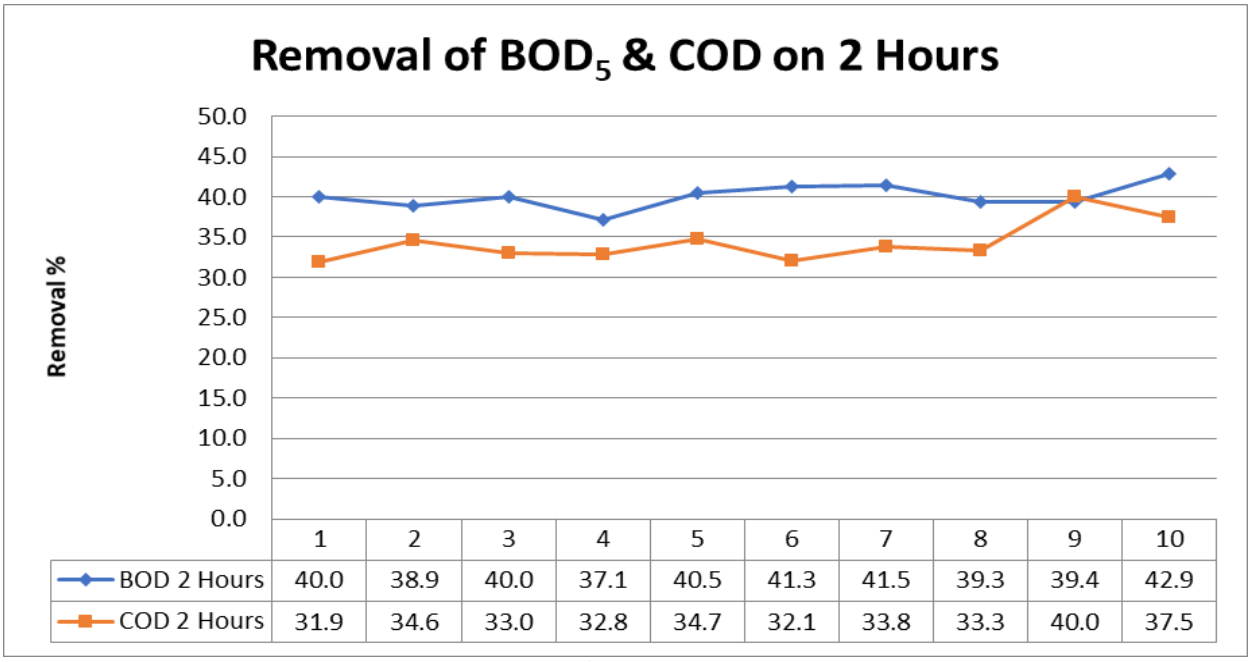
To reveal the consequences of the research, testing H_0: $\mu_1 = \mu_2$is equivalent; following Hypothesis is going to be established.

H_o:μ_d=0(there is no difference in the average removal of BOD_5 and COD observations in 2, 2.5 and 3 Hours)

H_a:$\mu_d \neq 0$ (there is difference in the average removal of BOD_5 and COD observations in 2, 2.5 and 3 Hours)

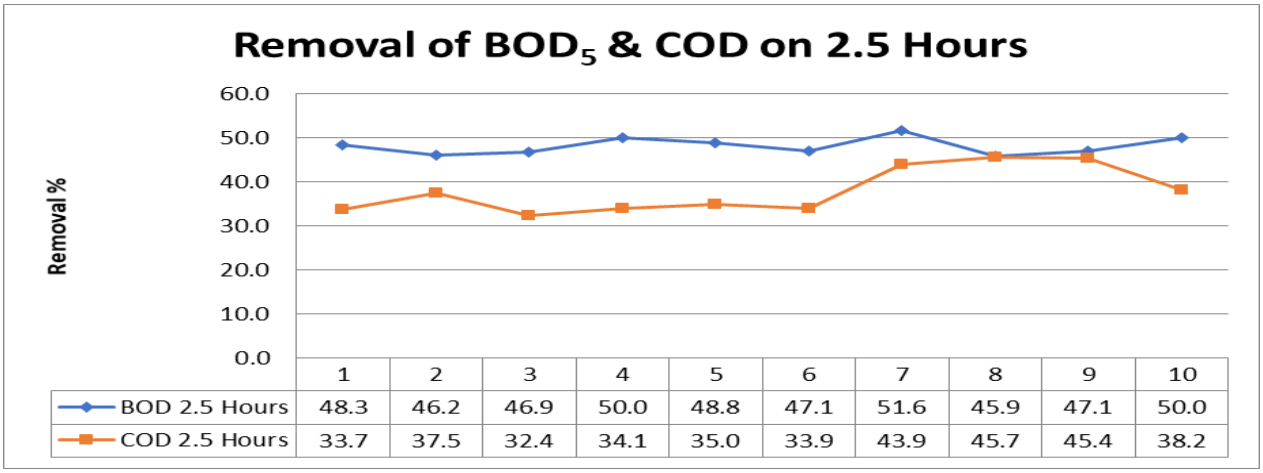
III. MATERIALS AND METHODS

The paired t- test technique is used on "Rotating Biological Contactor" in actually which is used in imitation for treatment of wastewater. The paired t- test is one sample t test simply, with null hypothesis $H_0 = 0$, applied to a population of paired differences in mean observations. Design used for this study is called paired comparison design, which illustrates the blocking principles. The term block refers to a relatively homogenous experimental unit as in this study the observations BOD_5 and COD are blocks. To check the performance of Rotating Biological contactor regarding the average removal of BOD_5 and COD, following study was conducted in Sindh University hostels through one factor, i.e. HRT, affecting the performance of RBC. in the present study to confirm the performance in order to BOD_5 and COD, multiple procedures of HRTs i.e. 2 hours (0.42 l/min), 2.5 hours (0.33 l/min) and 3 hours (0.28 l/min) respectively with 40 numbers of discs in RBC were applied and consequences were noted. The average removal of BOD_5 at 2 hours (0.42 l/min) is compared through paired t- test with the average removal of COD at 2 hours (0.42 l/min), 2.5 hours (0.33 l/min) removal of BOD_5 with the removal of COD of same HRT and at 3 hours (0.28 l/min) removal of BOD_5 with the COD removal of same HRT.



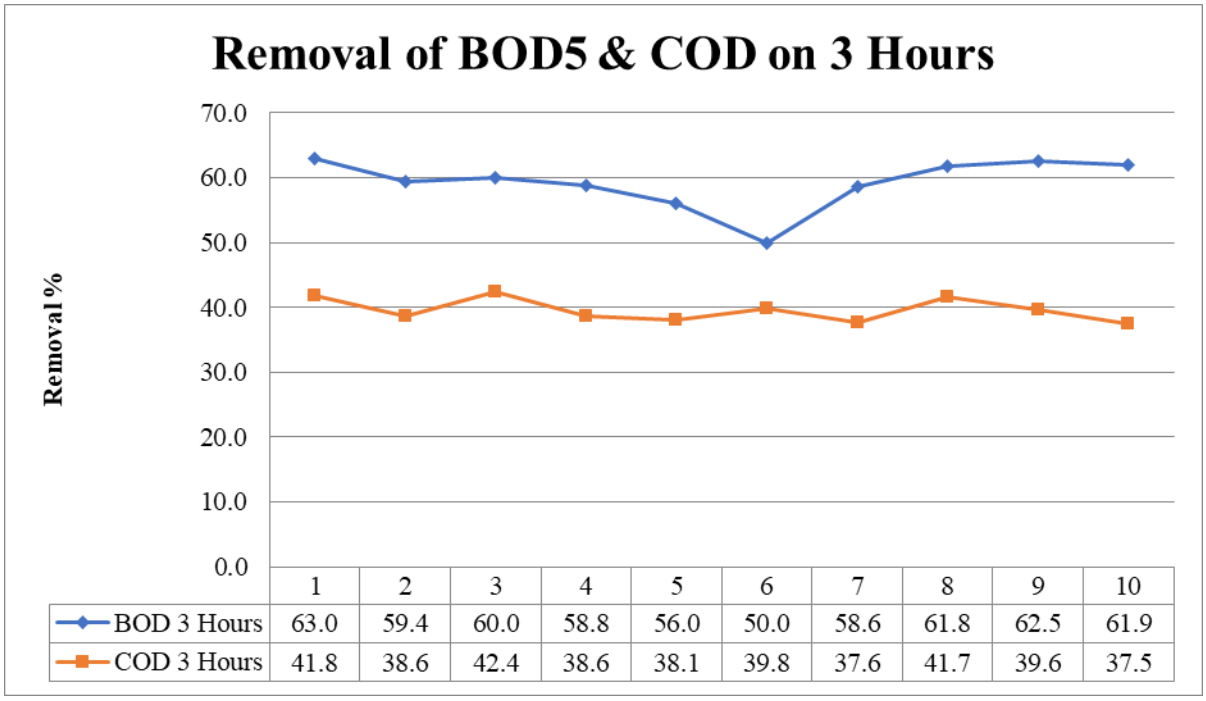
	1	2	3	4	5	6	7	8	9	10
BOD 2 Hours	40.0	38.9	40.0	37.1	40.5	41.3	41.5	39.3	39.4	42.9
COD 2 Hours	31.9	34.6	33.0	32.8	34.7	32.1	33.8	33.3	40.0	37.5

Fig. 1: Line chart showing removal % of BOD_5 and COD at 2 hours (0.42 l/min) through RBC.



	1	2	3	4	5	6	7	8	9	10
BOD 2.5 Hours	48.3	46.2	46.9	50.0	48.8	47.1	51.6	45.9	47.1	50.0
COD 2.5 Hours	33.7	37.5	32.4	34.1	35.0	33.9	43.9	45.7	45.4	38.2

Fig. 2: Line chart showing removal % of BOD_5 and COD at 2.5 hours (0.33 l/min) through RBC.



	1	2	3	4	5	6	7	8	9	10
BOD 3 Hours	63.0	59.4	60.0	58.8	56.0	50.0	58.6	61.8	62.5	61.9
COD 3 Hours	41.8	38.6	42.4	38.6	38.1	39.8	37.6	41.7	39.6	37.5

Fig. 3: Line chart showing removal % of BOD_5 and COD at 3 hours (0.28 l/min) through RBC

For the present study paired t- test is used to compare population means of removal of BOD_5 andCOD at different HRTs. The expected values of these differences are,

$\mu_d = E(d_j) = \mu_1 \_ \mu_2$

Inferences can be made about the differences in the mean removal of BOD_5 and COD by $\mu_1 \_ \mu_2$ by making conclusions about the average of the removal differences μ_d.

Testing the null hypothesis $H_0: \mu_1 \_ \mu_2$ is equivalent to testing

$H_o: \mu_d = 0$

$H_a: \mu_d \neq 0$

Test statistic for this hypothesis is $t_0 =$

$$\frac{\bar{d}}{s_d/\sqrt{n}}$$

Where $\bar{d}$ is the sample mean of the differences and S_d is the sample standard deviation of the differences(Douglas C. Montgomery 2005). Null hypothesis would be rejected if $t_0 > t_{\alpha/2,n-1}$ otherwise accepted.

IV. RESULTS AND DISCUSSION

Present study was conducted to apply the paired comparison design t- test for association the population means of the removal of BOD_5 and COD at different HRTs from greywater through RBC. This special technique called randomized block design provides the method for comparing two population means. As the observations on each experimental unit from the factor levels are paired that's why the procedure is called paired t- test.

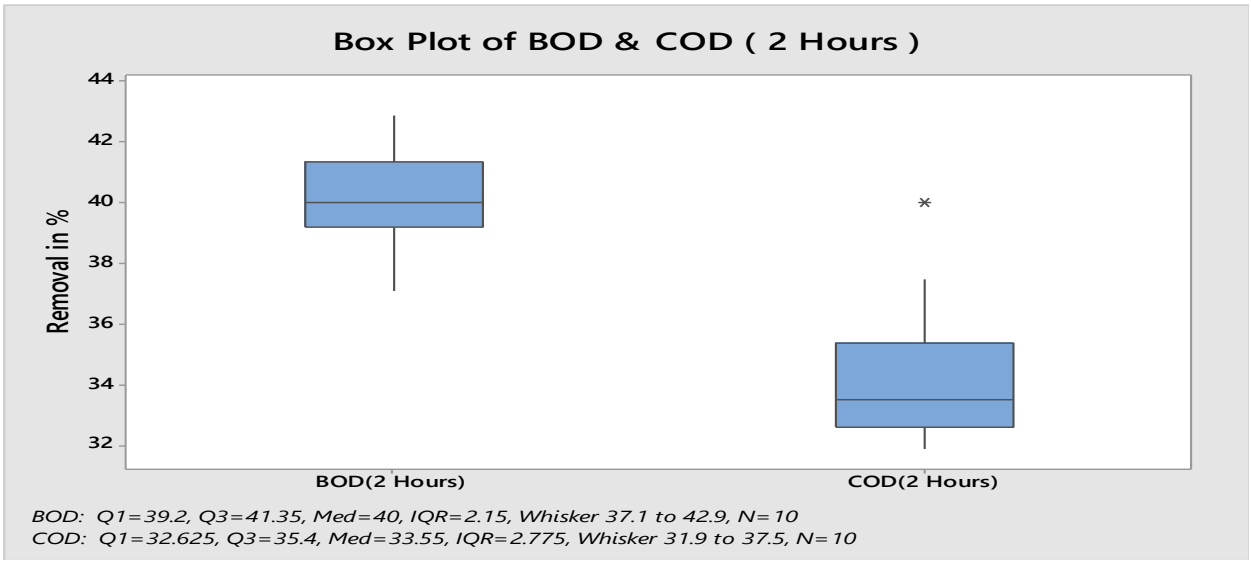


Fig. 1: The Box plotshowing the removal in % of BOD_5& COD in 2 Hours

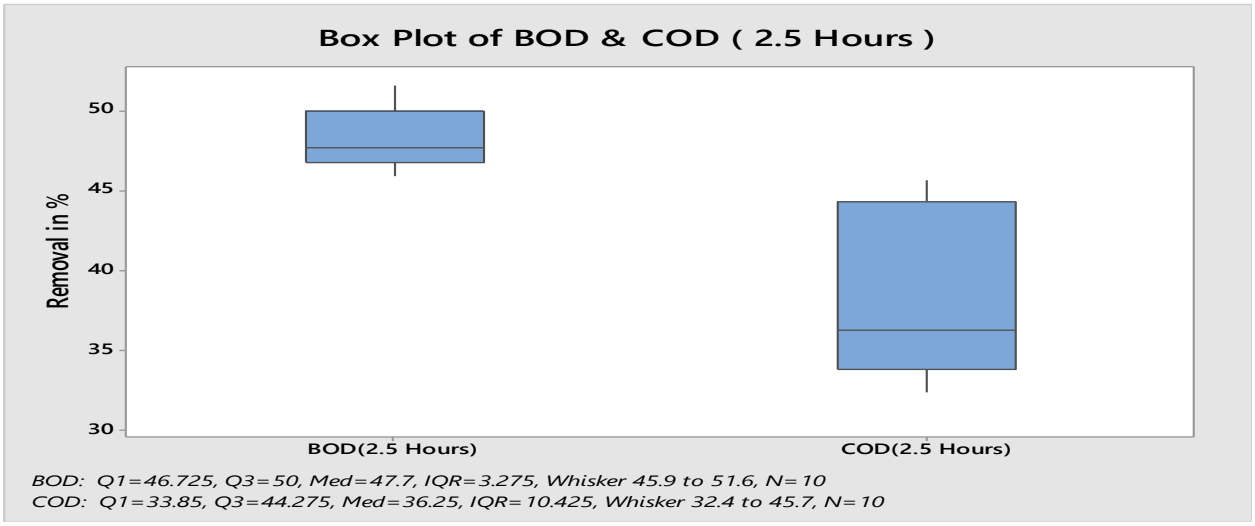


Figure 2: The Box plotshowing the removal in % of BOD_5& COD in 2.5 Hours

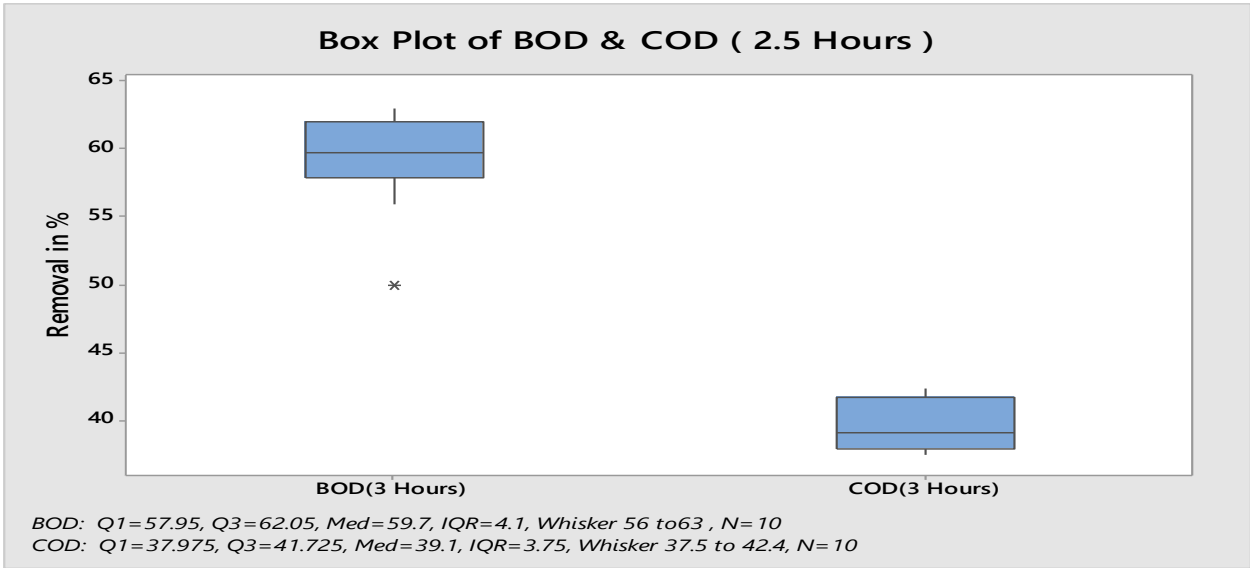


Fig. 3: The Box plotshowing the removal in % of BOD_5& COD in 3 Hours

Figure 1 to 3 provides the Box plots showing the removal in % of BOD_5& COD in different HRTs levels. The Box plots revealed that the removal % of BOD_5 is much better than the removal % of COD at all HRTs. Consequently, it is stated that the RBC is much effective technique for the removal of BOD_5 instead of COD.

Table 1: Paired T-Test interpretation of BOD_5 & COD on different Hydraulic Retention Time

	Average Removal %of BOD_5	Average Removal % of COD	Mean Difference	T- Value	$t_{\alpha/2,n-1}$	P-Value
2 Hours	40.090	34.370	5.720	6.61	2.262	0.000
2.5 Hours	48.19	37.98	10.21	5.83	2.262	0.000
3 Hours	59.20	39.57	19.63	15.98	2.262	0.000

Table revealed that the average removal % of BOD_5 is 40.090 and 34.370 of COD with mean difference 5.720 respectively at 2 hours. At 2.5 hours the average removal was 48.19 and 37.98 with mean difference 10.21 andat 3 hours the average removal of BOD_5 was 59.20 and 39.57 with mean difference of 19.63.Facts implies that removal% of BOD_5 is much better than COD through RBC.The computed values of paired t- test statistic are 6.61, 5.83 and 15.98 at 2 hours (0.42 l/min), 2.5 hours (0.33 l/min) respectively. And all these three t-value 6.61, 5.83 and 15.98 are > the $\mathbf{t_{\alpha/2,n-1}} = 2.262$, that's why reject all three null hypothesis $H_0: \mu_d \neq 0$. That there is sufficient evidence to indicate that the removal % of all HRTs is not same. Notice that the p- values of all HRTs are also even less then 0.01, while level of significance was 0.05. It implies that we reject the null hypothesis at any reasonable level of significance.

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