EVALUATING STRENGTH OF DESIGN CONCRETE MIX WITH DIFFERENT AGGREGATES USING VACUUM DEWATERED PROCESS

Mayank Varshney, Meenu Varshney, Manish Jangid

Abstract— **To produce Concrete of required strength one of the key factors is to have optimum water required. Vacuum dewatering is a process of extracting the excess water from the concrete after placing & compaction. Various Design Mixes having aggregates such as Sand, Stone Dust & Fly Ash can be tested to achieve the required strength. The study and laboratory test is focused on determining the strength of mix design of concrete by normal conventional way & using vacuum dewatered process in which the extra water is removed from concrete. After testing & comparing the results it was found that the strength parameters improved after vacuum dewatering of concrete mix prepared by different aggregates.**

***Index Terms*— Design mix, vacuum dewatering, aggregates, sand, stone dust, fly ash, cube test, compressive strength, flexural strength, water-cement ratio**

I. INTRODUCTION

1.1 General

A high quality concrete floor or pavement requires not only to be level but it should also have high wear resistance, high compressive strength, reduced shrinkage and minimum water permeability. Lowered water cement ratio automatically leads to a noticeable improvement in almost each of the concrete properties. The key to the use of this method is the dewatering of concrete by vacuum process. Surplus water from the concrete is removed immediately after placing and vibration, reducing the water: cement ratio to an optimum level.

The stresses induced in concrete pavements are mainly flexural. Therefore flexural strength is more often specified than compressive strength in the design of concrete mixes for pavement construction. A simple method of concrete mix design based on flexural strength for normal weight concrete mixes is described in the paper.

Usual criterion for the strength of concrete in the building industry is the compressive strength, which is considered as a measure of quality concrete. However, in pavement constructions, such as highway and airport runway, the flexural strength of concrete is considered more important, as the stresses induced in concrete pavements are mainly flexural. Therefore, flexural strength is more often specified than compressive strength in the design of concrete mixes for pavement construction. It is not perfectly reliable to predict flexural strength from compressive strength. Further, various codes of the world specified that the paving concrete mixes should preferably be designed in the laboratory and controlled in the field on the basis of its flexural strength. Therefore, there is a need to design concrete mixes based on flexural strength.

Concrete is the basic engineering material used in most of the civil engineering structures. Its popularity as basic building material in construction is because of, its economy of use, good durability and ease with which it can be manufactured at site. The ability to mould it into any shape and size, because of its plasticity in green stage and its subsequent hardening to achieve strength, is particularly useful.

Concrete like other engineering materials needs to be designed for properties like strength, durability, workability and cohesion. Concrete mix design is the science of deciding relative proportions of ingredients of concrete, to achieve the desired properties in the most economical way.

1.2 Objective of the study

The aim in vacuum dewatering is to remove as much as possible ,the portion of the mix water introduced for workability. The amount generally is two to four times as much as the amount required for hydration of the cement. Water not needed for hydration but left in the concrete after placing and finishing is a drawback in that it leads to lower strength, a decreased rate of strength gain, increased shrinkage and creep and more susceptibility to frost damage.

The type of aggregate can have a predominant effect, crushed rock aggregate resulting in concrete with higher flexural strength than uncrushed (gravel) aggregates for comparable mixes, assuming that sound materials are used. The strength of cement influences the compressive and flexural strength of concrete i.e. with the same water-cement ratio; higher strength cement will produce concrete of higher compressive and flexural strength.

With advent of high-rise buildings and pre-stressed concrete, use of higher grades of concrete are becoming more common. Even the revised IS 456-2000 advocates use of higher grade of concrete for more severe conditions of exposure, for durability considerations.

With advent of new generation admixtures; it is possible to achieve higher grades of concrete with high workability levels economically. Use of mineral admixtures like fly ash, slag, meta kaolin and silica fume have revolutionised the concrete technology by increasing strength and durability of concrete by many folds. Mix design of concrete is becoming more relevant in the above-mentioned scenario.

However, it should be borne in mind that mix design when adopted at site should be implemented with proper understanding and with necessary precautions.

II. LITERATURE REVIEW

2.1 Background

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Mayank Varshney, Professor, Department of Civil Engg., Jagannath University, Jaipur

Meenu Varshney, Associate Professor, Department of Architecture & Planning, M.N.I.T ,Jaipur

Manish Jangid, Junior Engineer, Jaipur Development Authority, Jaipur

The Romans developed a method of dewatering concrete: they stuck brick and lava chips into it; the chips protruded above the surface and acted as wicks to draw water from the concrete. Their literature shows that Vitruvius understood the advantages of lowering the water cement ratio. In the United States, dewatering of concrete by vacuum was patented in 1935 by K. P. Billner and all subsequent development has been based on his extensive ideas. His method was used in the 1940's and early 1950's, with the last known practical application in the United States being in 1965. Vacuum dewatering got a new lease on life mainly after two or three Scandinavian firms succeeded in simplifying the equipment enough to make it practical for almost any builder. Dewatering can produce the kind of improvement in compressive strength. In Sweden the method is now used for 40 to 50 percent of all floors. Its use in wall, column and other construction is rare.

2.2 Concrete Mix design

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible. From technical point of view the rich mixes may lead to high shrinkage and cracking in the structural concrete, and to evolution of high heat of hydration in mass concrete which may cause cracking.

The actual cost of concrete is related to the cost of materials required for producing a minimum mean strength called characteristic strength that is specified by the designer of the structure. This depends on the quality control measures, but there is no doubt that the quality control adds to the cost of concrete. The extent of quality control is often an economic compromise, and depends on the size and type of job. The cost of labour depends on the workability of mix, e.g., a concrete mix of inadequate workability may result in a high cost of labour to obtain a degree of compaction with available equipment.

III. DESIGN OF CONCRETE MIXES

3.1.1 Concrete mix design with sand

Parameters for mix design:-

Grade Designation = M 35
Type of cement = O.P.C.-43 grade
Brand of cement = J.K. Laxmi
Admixture = Fosroc (Conplast SP 430 G8M)
Fine Aggregate = Zone-II
Sp. Gravity Cement = 3.15
Fine Aggregate = 2.69
Coarse Aggregate (20 mm) = 2.61
Coarse Aggregate (10 mm) = 2.46
Minimum Cement = 300 kg/m^3
Maximum water cement ratio = 0.45

Target Strength for Mix Proportioning

$\overline{f_{ck}} = f_{ck} + 1.65 \times S$
$\overline{f_{ck}} = f_{ck} + 13$
Target Strength = 35 + 13 = 48N/ mm^2

Mix Calculation:-

Cement = 400 kg
Water = 161 kg
Fa/Ca = 40/60
W/C = 0.37
S_{fa}= 2.69
S_{ca} = 2.61
Volume of concrete = 1 cum.
Volume of cement = (366/3.15) X (1/1000) = 0.116 Cum
Volume of water = (154/1) X (1/1000) = 0.154 Cum.
Volume of Admixture
@ 1 % wt. of cement = (3.66/1.0) X (1/1000) = 0.003 Cum.
Volume of all in Aggregate = 1- (0.116 + 0.154 + 0.003)
= 1 – 0.273
= 0.727 Cum.
Mass of coarse Aggregate = 0.727 X 0.60 X 2.61 X 1000
= 1138.48 kg ~ 1138 kg
Mass of fine Aggregate = 0.727 X 0.40 X 2.69 X 1000
= 764.80 ~ 765 kg

Table No. 3.1 M-35 design mix with sand

Concrete	Cement	Water	Sand	10 mm	20 mm	Admixture
1 Cum	366	154	765	569	569	1 % wt. of cement

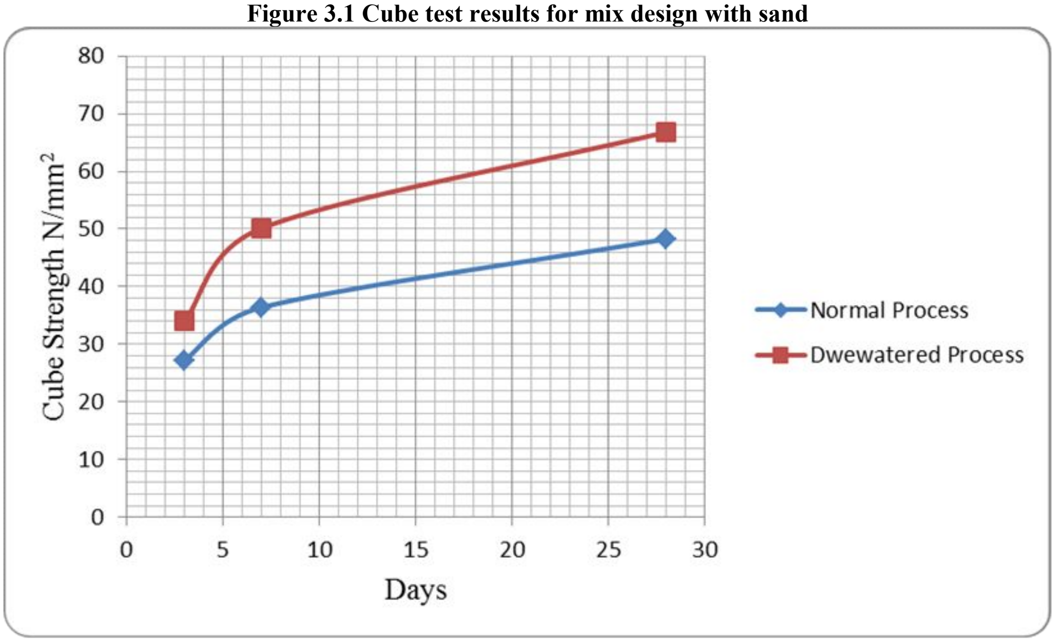
Table No. 3.2 M-35 design mix with sand cube test results

Cross Sectional Area of Cube is 15 cm X 15 cm = 225 Sq. Cm.

Cube Mark	Date of Casting	Date of Testing	Max. Load (kN)	Compressive Strength (N/mm^2)	Avg. Compressive StrengthN/mm^2	Weights(g)
3 days						
Normal Process						
1	6/12/14	9/12/14	612	27.2	27.2	8392.0

2	6/12/14	9/12/14	621	27.6		8402.0
3	6/12/14	9/12/14	615	26.8		8390.0
Dewatered Process						
1	6/12/14	9/12/14	765	34	34	8397
2	6/12/14	9/12/14	810	36		8420
3	6/12/14	9/12/14	720	32		8412
7 days						
Normal Process						
1	6/12/14	13/12/14	819	36.4	36.4	8391
2	6/12/14	13/12/14	828	36.8		8412
3	6/12/14	13/12/14	810	36		8421
Dewatered Process						
1	6/12/14	13/12/14	1125	50	50.13	8424
2	6/12/14	13/12/14	1143	50.8		8410
3	6/12/14	13/12/14	1116	49.6		8403
28 days						
Normal Process						
1	6/12/14	3/01/15	1089	48.4	48.26	8390
2	6/12/14	3/01/15	1098	48.8		8421
3	6/12/14	3/01/15	1071	47.6		8406
Dewatered Process						
1	6/12/14	3/01/15	1494	66.4	66.80	8431
2	6/12/14	3/01/15	1512	67.2		8421
3	6/12/14	3/01/15	1503	66.8		8398

Figure 3.1 Cube test results for mix design with sand



3.1.2 Concrete mix design with stone dust

Parameters for mix design:-

Grade Designation = M 35
Type of cement = O.P.C.-43 grade
Brand of cement = J.K. Laxmi
Admixture = Fosroc (Conplast SP 430 G8M)
Fine Aggregate = Zone-II
Sp. Gravity Cement = 3.15
Fine Aggregate = 2.69
Coarse Aggregate (20 mm) = 2.61
Coarse Aggregate (10 mm) = 2.46
Minimum Cement = 300 kg/m^3

Maximum water cement ratio = 0.45

Target Strength for Mix Proportioning

$\overline{f_{ck}} = f_{ck} + 1.65 \times S$

$\overline{f_{ck}} = f_{ck} + 13$

Target Strength = 35 + 13= 48N/ mm^2

Mix Calculation:-

Cement = 400 kg

Water = 164 kg

Fa/Ca = 40/60

W/C = 0.42

S_{fa}= 2.69

S_{ca} = 2.61

Volume of concrete = 1 cum.

Volume of cement = (400/3.15) X (1/1000) = 0.126 Cum

Volume of water = (164/1) X (1/1000) = 0.164 Cum.

Volume of Admixture

@ 1 % wt. of cement = (4.00/1.0) X (1/1000) = 0.004 Cum.

Volume of all in Aggregate = 1- (0.126 + 0.164 + 0.004)

= 1 – 0.294

= 0.706 Cum.

Mass of coarse Aggregate = 0.706 X 0.60 X 2.61 X 1000

= 1105.59 kg ~ 1106 kg

Mass of fine Aggregate = 0.706 X 0.40 X 2.69 X 1000

=759.65 ~ 760 kg

Table No. 3.3 M-35 design mix with stone dust

Concrete	Cement	Water	Sand	10 mm	20 mm	Admixture
1 Cum	400	164	760	553	553	1 % wt. of cement

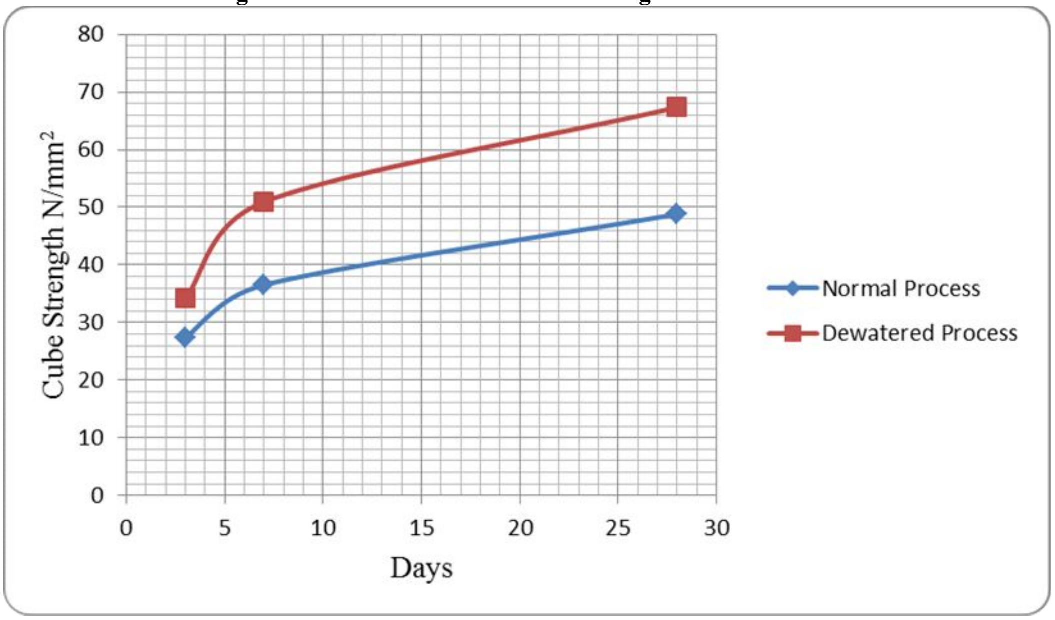
Table No. 3.4 M-35 design mix with stone dust cube test results

Cross Sectional Area of Cube is 15 cm X 15 cm = 225 Sq. Cm.

Cube Mark	Date of Casting	Date of Testing	Max. Load (kN)	Compressive Strength (N/mm^2)	Avg. Compressive StrengthN/mm^2	Weights(g)
3 days						
Normal Process						
1	27/12/14	30/12/14	621	27.6	27.42	8421
2	27/12/14	30/12/14	603	26.8		8412
3	27/12/14	30/12/14	630	28		8417
Dewatered Process						
1	27/12/14	30/12/14	783	34.8	34.26	8398
2	27/12/14	30/12/14	756	33.6		8425
3	27/12/14	30/12/14	774	34.4		8412
7 days						
Normal Process						
1	27/12/14	3/01/15	855	38	36.53	8387
2	27/12/14	3/01/15	801	35.6		8426
3	27/12/14	3/01/15	810	36		8418
Dewatered Process						
1	27/12/14	3/01/15	1170	52	50.93	8408
2	27/12/14	3/01/15	1116	49.6		8427
3	27/12/14	3/01/15	1152	51.2		8396
28 days						
Normal Process						
1	27/12/14	24/01/15	1107	49.2	48.8	8431
2	27/12/14	24/01/15	1089	48.4		8404
3	27/12/14	24/01/15	1098	48.8		8415
Dewatered Process						

1	27/12/14	24/01/15	1530	68	67.33	8403
2	27/12/14	24/01/15	1503	66.8		8412
3	27/12/14	24/01/15	1521	67.6		8416

Figure 3.2 Cube test results for mix design with Stone Dust



3.1.3 Concrete mix design with Flyash

Parameters for mix design:-

Grade Designation = M 35
Type of cement = O.P.C.-43 grade
Brand of cement = J.K. Laxmi
Admixture = Fosroc (Conplast SP 430 G8M)
Fine Aggregate = Zone-II
Sp. Gravity Cement = 3.15
Fine Aggregate = 2.69
Coarse Aggregate (20 mm) = 2.61
Coarse Aggregate (10 mm) = 2.46
Minimum Cement = 300 kg/m^3
Maximum water cement ratio = 0.45

Target Strength for Mix Proportioning

$\overline{f_{ck}} = f_{ck} + 1.65 \text{ x } S$
$f_{ck} = f_{ck} + 13$
Target Strength = 35 + 13 = 48N/ mm^2

Mix Calculation:-

Cement = 300 kg
Flyash = 100 kg
Water = 168 kg
Fa/Ca = 40/60
W/C = 0.42
S_{fa}= 2.69
S_{ca} = 2.61
Volume of concrete = 1 cum.
Volume of cement = (300/3.15) X (1/1000) = 0.095 Cum
Volume of flyash = (100/3.15) X (1/1000) = 0.033 Cum
Volume of water = (168/1) X (1/1000) = 0.168 Cum.
Volume of Admixture
@ 1 % wt. of cement = (3.00/1.0) X (1/1000) = 0.003 Cum.
Volume of all in Aggregate = 1- (0.095 + 0.033 +0.168+ 0.003)
= 1 – 0.299
= 0.701 Cum.
Mass of coarse Aggregate = 0.701 X 0.60 X 2.61 X 1000

= 1097.76 kg ~ 1098 kg
Mass of fine Aggregate = 0.701 X 0.40 X 2.69 X 1000
=754.27 ~ 754 kg

Table No. 3.5 M-35 design mix with flyash

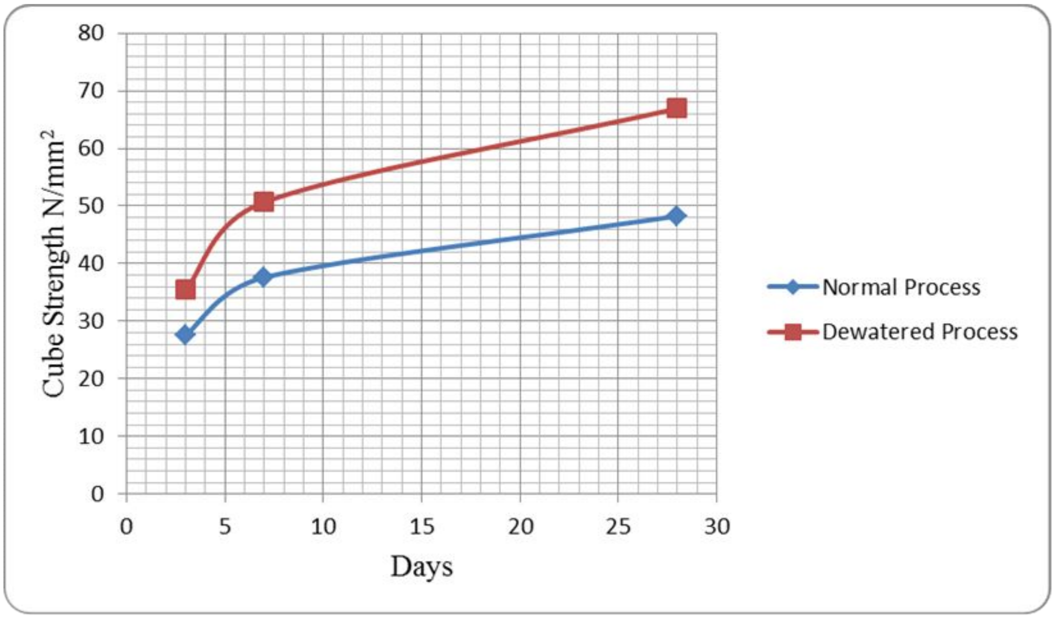
Concrete	Cement	Water	Sand	10 mm	20 mm	Admixture
1 Cum	400	168	754	549	549	1 % wt. of cement

Table No. 3.6 M-35 design mix with stone dust cube test results

Cross Sectional Area of Cube is 15 cm X 15 cm = 225 Sq. Cm.

Cube Mark	Date of Casting	Date of Testing	Max. Load (kN)	Compressive Strength (N/mm^2)	Avg. Compressive StrengthN/mm^2	Weights(g)
3 days						
Normal Process						
1	17/01/15	20/01/15	612	27.2	27.60	8405
2	17/01/15	20/01/15	603	26.8		8998
3	17/01/15	20/01/15	639	28.4		8420
Dewatered Process						
1	17/01/15	20/01/15	774	34.4	35.47	8405
2	17/01/15	20/01/15	756	36.8		8413
3	17/01/15	20/01/15	774	35.2		8431
7 days						
Normal Process						
1	17/01/15	24/01/15	837	37.2	37.6	8415
2	17/01/15	24/01/15	864	38.4		8418
3	17/01/15	24/01/15	837	37.2		8400
Dewatered Process						
1	17/01/15	24/01/15	1125	50	50.67	8423
2	17/01/15	24/01/15	1161	51.6		8993
3	17/01/15	24/01/15	1134	50.4		8410
28 days						
Normal Process						
1	17/01/15	14/02/15	1089	48.4	48.26	8436
2	17/01/15	14/02/15	1098	48.8		8432
3	17/01/15	14/02/15	1071	47.6		8402
Dewatered Process						
1	17/01/15	14/02/15	1485	66	66.93	8399
2	17/01/15	14/02/15	1521	67.6		8423
3	17/01/15	14/02/15	1512	67.2		8429

Figure 3.3 Cube test results for mix design with Flya



4. INTERPRETATION OF RESULTS

4.1 Advantage of vacuum dewatered concrete

A well mix design of concrete for vacuum dewatered concrete will result in following advantages:

- Increase in the compressive strength by 40 - 70% (higher increase is at the top surface)
- Increase in Wear Resistance by 100 - 150%.
- Shrinkage of Vacuum treated concrete will be reduced by about 150%.
- Strength gain in Vacuum concrete is earlier than normal way thus earlier utilization is possible.
- In vacuum dewatered concrete high compressive strength minimum water permeability and should minimize dusting at bare minimum cost.
- A vibration operation had increased the water-cement ratio at the surface and reduced at the bottom.
- The cement content had been increased in the same operation at the surface and decreased it at the base.
- During vacuum treatment the water content were extracted to 19.5 percent of the original water. The water content at the base was reduced. At the surface, where the water content had increased during vibration, it was decreased during vacuum treatment. Thus the effect of the treatment was highest close to the surface and gradually diminished toward the base.
- The influence of the vacuum treatment on the concrete is quite dramatic. Surface quality had been improved by the increase in cement content during vibration and the decrease in water content during vacuum treatment.

4.2 Benefits of vacuum dewatered concrete mix design

Mix design aims to achieve good quality concrete at site economically.

1. **Quality concrete means**

A. Better strength
B. Better imperviousness and durability
C. Dense and homogeneous concrete

2. **Economy**

A. Economy in cement consumption :

It is possible to save up to 20% of cement for M 35 grade of concrete with the help of concrete mix design. In fact higher the grade of concrete more are the savings.

B. Best use of available materials:

Site conditions often restrict the quality and quantity of ingredient materials. Concrete mix design offers a lot of flexibility on type of aggregates to be used in mix design. Mix design can give an economical solution based on the available materials if they meet the basic IS requirements.

C. Other properties:

Mix design can help us to achieve form finishes, high early strengths for early de shuttering, concrete with better flexural strengths, concrete with pump ability and concrete with lower densities.

4.3. Comparison between Normal concrete and Vacuum dewatered concrete

The comparison between Normal concrete and vacuum dewatered concrete is given in table :

Table No. 4.1 M-35 Comparison between Normal concrete and Vacuum dewatered concrete

Sl. No.	Properties	Vacuum dewatered concrete	Normal concrete
1	Water Cement ratio	Less	More
2	Comparative Strength	More	Less
3	Heat of hydration	Less	More
4	Cement Contain	Less	More
5	Flexure Strength	More	Less
6	Shrinkage	Less	More

7	Creep	Less	More
8	Life Cycle	More	Less

P-12:- Casted concrete cubes`

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The durability of vacuum dewatered concrete is much compared with the normal concrete. Vacuum dewatered concrete found better than the conventional ones. The strength of vacuum dewatered concrete is more than normal concrete. Life age of this type of concrete is more than the normal concrete. Decrease in the water cement ratio increases the strength of concrete. The concrete with the waste material also gives good results. The shrinkage and creep produce in vacuum dewatered concrete is very low. The consumption of cement decreases by using vacuum dewatered system.

Based on the study it can be concluded that the decreasing water cement ratio increases the strength of concrete. The additional water used in concrete for workability is extracted by vacuum dewatered process and it decreases the water cement ratio which increases the strength of concrete.

5.2 Recommendations

Vacuum dewatered system increase the strength of concrete. The use of innovative technology not only increases the strength but also increases the concrete life as well as will help to improve the environment. The dewatered concrete would be a boon for India's hot and extremely humid climate, where temperature frequently crosses 50 ^{o}C and torrential rains create havoc, leaving most of the concrete with shrinkage and creep. It is hoped that in near future we will have strong, durable and eco-friendly concrete with vacuum dewatering process.

The generation of concrete is increasing day by day. The major consumption of concrete in the field of infrastructure division having roads, bridges, etc. For these types of structures need very high grade of concrete, which increase the consumption of cement and steel as well as cost of the structure. By using the vacuum dewatered process it decreases the consumption of cement and steel as well as overall cost of the structure.

REFERENCES

[1] Specification for Road and Bridge works by Ministry of Shipping, Road Transport & Highways (MSRT&H).
[2] Khanna S.K & Justo C.E.G: "Highway Engineering"
[3] Gambhir M.L : "Concrete Manual"
[4] Shetty M.L: "Concrete Technology"
[5] Punmia B.C: "Building Materials"
[6] IS 456 : 2000 –"Plain and Reinforced Concrete - Code of Practice"
[7] IS 8112 : 1989 –"Specification for 43 grade ordinary Portland cement"
[8] IS 12269 : 1987-"Specification for 53 grade ordinary Portland cement"
[9] IS 383 : 1970-"Specification for coarse and fine aggregates from natural sources for concrete"
[10] 10262 : 2009 –"Recommended guidelines for concrete mix design"

LIST OF WEBSITES VISITED

www.engineeringcivil.com
www.scribd.com
www.icjonline.com
www.enjineer.com
www.icpeenvis.com