Volume-2, Issue-1

SREEPATHY
JOURNAL OF CIVIL ENGINEERING

Published by
Department of Civil Engineering
Sreepathy Institute of Management and Technology, Vavanoor
Palakkad - 679 533

July 2015

Contents

ANALYSIS AND DESIGN OF A PRESTRESSED CONCRETE GIRDER

*Ms. RESHMA THILAK, * Ms. ANJALI P., * Mr. ANANDH C. S., * Ms. ANU K. PAUL, * Ms. ATHIRA M. V.

*Graduate students

Department of Civil Engineering

Sreepathy Institute of Management & Technology, Vavanoor, India

ABSTRACT

The concept of pre-stressed concrete appeared in the year 1888. In this present engineering technology durable and sustainable bridges play an important role for the socio-economic development of the nation. Owners and designers have long recognized the low initial cost, low maintenance needs and long life expectancy of pre-stressed concrete bridges. This is reflected in the increasing market share of pre-stressed concrete, which has grown from zero in 1950 to more than 55 percent today. In this present study design of prestressed concrete girder is presented. This paper introduces a new concept of integral Bridge in which having no expansion joints or sliding bearings, the deck is continuous across the length of the bridge which increases the durability and seismic performances. The aim and objective can be summarized as to analyze and design the PSC girder under a IRC class A loading, To formulate the entire problem for a single span under the loading mentioned above, to obtain shear force and bending moment at regular intervals along the beam, To use the software SAP 2000 for the analysis and design of prestressed concrete girders.This paper completely going to do in a practical approach that on a major bridge having 6 span, each of 35m long and 18 no's of PSC Beams

Key words — Prestressed concrete, I girder, Integral Bridges ,SAP 2000

I. INTRODUCTION:

Bridge is life line of road network, both in urban and rural areas. With rapid technology growth the conventional bridge has been replaced by innovative cost effective structural system. Prestressed concrete is basically concrete in which internal stresses of suitable magnitude and distribution are introduced so that the stresses resulting from external loads are counteracted to a desired degree. In reinforced concrete members, the prestress is commonly introduced by tensioning the steel reinforcement. The development of early cracks in reinforced concrete due to incompatibility in the strains of steel and concrete was perhaps the starting point in the development of a new material like "prestressed concrete". The application of permanent compressive stress to a material like concrete, which is strong in compression but weak in tension, increases the apparent tensile strength of that material, because the subsequent application of tensile stress must first nullify the compressive prestress. In 1904, Freyssinet attempted to introduce permanently acting forces in concrete to resist the elastic forces developed under the name of "prestressing".

PSC beam design is more complicated as structure is more complex as well as needed sophisticated from work. Bridge design is an important as well as complex approach of structural engineer. As in case of bridge design, span length and live load are always important factor. These factors affect the conceptualization stage of design.

II. PRESTRESSED CONCRETE BRIDGES

III.

Prestressed concrete is ideally suited for the construction of medium and long span bridges. The material has found extensive application in the construction of long span bridges, gradually replacing steel which needs costly maintenance due to the inherent disadvantages of corrosion under aggressive atmospheric condition.

- High –strength concrete and high tensile steel, besides being economical, make for slender section, which are aesthetically superior.
- Prestressed concrete bridge can be designed as class 1 type structures without any tensile stress under service load, thus resulting in a crack – free structures.
- In comparison with steel bridges, prestressed concrete bridges require very little maintenance.
- Prestressed concrete is ideally suited for composite bridge construction in which precast prestressed girder support the cast in situ slab deck. This type of construction is very popular since it involves minimum disruption of traffic.
- Post tensioned prestressed concrete finds extensive applications in long span continuous girder bridges of variable cross – section. Not only does it make for sleek structures, but it also affects considerable saving in the overall cost of construction.
- In recent years, partially prestressed concrete has been preferred for bridge construction, because it offers economy in the use of high tensile steel in the girder.

IV. INTEGRAL BRIDGES

Integral bridges are the concrete bridge in which bearings are eliminated and expansion joints are eliminated or provided at longer distances. Bearings and expansion joints are weakest link in the chain of durability and maintenance. Bearings are fragile and brittle elements of the bridge. Their failure can result in unseating of the superstructure. Expansion joints invariably get damaged during significant ground shaking.

Integral bridges have durability and enhanced seismic performances.

V. SAP 2000

Modelling, analysis and design of bridge structures have been integrated into CSiBridge to create the ultimate in computerized engineering tools. The ease with which all of these tasks can be accomplished makes SAP 2000 the most versatile and productive software program available on the market today. Using SAP 2000, engineers can easily define complex bridge geometries, boundary conditions and load cases.

Each and every component is divided into two categories, either into a shell element or beam element.

Table 4.1 Shell element and beam element

Shell element	Beam element
Deck slab	Girders
Abutment	Pier
Pile cap	Pier cap
	Pile

3-D view

VI. METHOD OF ANALYSIS

The bridge is analyzed for various types of loads mentioned below

- Dead load
- Live load
- Impact load
- Longitudinal force
- Wind load
- Seismic load

This Bridge is designed for IRC class A , two lane loads. Class A loading consists of a wheel load train composed of a driving vehicle and two trailers of specified axle spacing. This loading is normally adopted on all roads on which permanent bridges are constructed.

VI. DESIGN

A. Background information

- Span arrangement; Post-tensioned Concrete Girder Bridge for a length of 210m with 6 spans of 35 m each for two Lane Bridge with 1500 mm wide foot path is proposed to construct between Paruthur and Irimbiliyam.
- A constant deck width of 11.23m is assumed.
- The span arrangements, six intermediate piers and two end abutment walls integrated to the pile caps.

B. Materials for Construction

M40 grade concrete with Portland Slag Cement and Fe 500 grade steel with very severe exposure condition as per IRC 112-2011 is assumed for super structure.

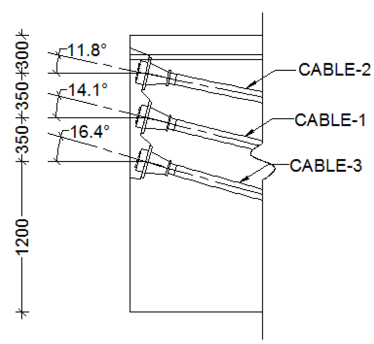
C. Method of analysis and Design

- A versatile finite element package (SAP 2000) is used for modelling and analyzing the structure.
- Deck slab is modelled using shell elements.
- Longitudinal girders and cross girders are modelled using beam elements.
- The loads of wearing coat, kerb, footpath slab and hand rails are considered as super imposed DL.
- The critical values of various moments and stresses are considered for Design of Deck Slab, Post-tensioned Girders and Cross Girders.
- The pile cap was modelled using shell elements and piles and piers as frame elements.
- The fixity depth of pile is considered as 10 times diameter of pile.
- The various elements of the bridge are designed as per the IRC 112-2011.

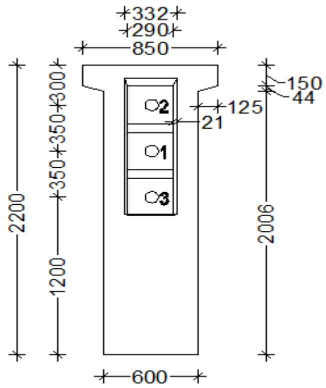
D. Pre-stressing System

Post tensioning method is adopted for pre-stressing.

- 12.7 mm nominal diameter strands of low relaxation type conforming to IS:14268-1995 are used.
- Based on the analysis, 3nos of 19T13 cables are proposed to be used.
- Sheathing internal dia=85mm,Strand Area =98.7mm^2;UTS =183.7 kN; f_{sy} =1860 MPa.
- Stressing shall be done in two stages.1st stage prestressing is done on the 7th day of casting of precast girders or when concrete attains a strength of 24mpa, Whichever is earlier. 2nd stage prestressing is done on the 14th day of casting of precast girders or when concrete attains a strength of 32mpa. whichever is later



Cable Arrangement In Elevation



Cable Arrangement At Endspan

C. Basic Data for Design

Effective Span	35m
Length of Girder	33.65 m
Grade of concrete	M40
Unit weight of concrete	25.0kN/m^3
Ec	33000 N/mm^2
Fs	1860.0 N/mm^2
Es	195000.0 N/mm^2
Area of prestressing strand	98.7mm^2
Diameter of Duct	85mm
Modular ratio	5.91

Calculation Of Prestressing Force And Eccentricity

- AT TRANSFER STAGE

Maximum moment at mid span = 3068.66 KNm
Section modulus at top = 0.0418 m^3
Section modulus at bottom = 0.39 m^3
Cross sectional area = 0.845 m^2
Allowable value of compression = 20 N/mm^2
Allowable value of tension = 2 N/mm^2
Therefore, Prestressing force, P = 7605 KN
Eccentricity, e = 0.46 m

Corresponding to this prestressing force, adopt a tendon of specification 19T13 ; Ultimate capacity = 3490 KN

- AT SERVICE STAGE

Jacking force = 2792 KN
Prestressing force, P(Assuming 10% loss) = 7276.31 KN
Stress at top, σ_{top} = 1.9 N/mm^2
Stress at top, σ_{bot} = 15.2 N/mm^2
Stresses are within the limits. Hence it is ok

- MAJOR CHECK AT SERVICE STAGE

Assume 30% loss in the prestressing force
Prestressing force, P = 5657.47 KN
Section modulus at top = 1.52X 10^9 m^3
Section modulus at bottom = 6.14X 10^8 m^3
Bending moment due to dead weight of girder, M_D = 1993.66 KNm
Bending moment due to dead weight of girder & Slab, M_{slab} = 1032.3 KNm
Bending moment due to superimposed dead load, M_{SIDL} = 789.42 KNm
Bending moment due to live load, M_{LL} = 1540.46 KNm
Stress at top, σ_{top} = -6.35 N/mm^2
Stress at top, σ_{bot} = 17.48 N/mm^2

For effective prestressing, stress at top should be equal to zero. After successive trial and error adopt, Prestressing force P = 2358 KN
Eccentricity, e = 1.016 m

Stresses at Transfer stage

1st stage stressing (Prestressing done to one cable)

Prestressing force = 2358 kN
Maximum Bending moment at midspan = 3069.45 kNm
Eccentricity at mid span = 1016mm
Section modulus at top = 0.0418 m^3
Section modulus at bottom = 0.3901 m^3
Cross sectional area = 0.8105 m^2
Stress at top = 18.89 N/mm^2
Stress at bottom = 1.06 N/mm^2

2nd stage stressing (Prestressing done to remaining two cables)

Prestressing force = 3893 kN
Maximum Bending moment at mid span = 6639.86 kNm
Eccentricity at mid span = 1648 mm
Section modulus at top = 0.3667 m^3
Section modulus at bottom = 0.4927 m^3
Cross sectional area = 1.375 m^2
Stress at top = 3.44 N/mm^2
Stress at bottom = 2.37 N/mm^2

As per IRC 112-2011,
Allowable value of compression = 0.5 f_{ck} = 20 N/mm^2
Allowable value of tension = 0.04 f_{ck} = 1.6 N/mm^2

The final stresses at transfer stage are within the limits given above. Hence it is ok.

Stresses at Service stage

Prestressing force = 3776.21 kN
Maximum Bending moment at midspan = 4511.66 kNm
Eccentricity at mid span = 1648.4 mm
Section modulus at top = 0.3667 m^3
Section modulus at bottom = 0.4927 m^3
Cross sectional area = 1.375 m^2
Stress at top = -1.92 N/mm^2
Stress at bottom = 6.22 N/mm^2

As per IRC 112-2011,
Allowable value of compression = 20 N/mm^2
Allowable value of tension = -3 N/mm^2

The final stresses at service stage are within the limits given above. Hence it is ok.

Check for ultimate Moment of Resistance and Ultimate shears

Though the design is done as per permissible stresses at the service load level, it is obligatory to check for the limit state capacity both for bending moment and shear force since there is no direct relationship between service loads and corresponding stresses and ultimate load and limiting stresses. As Per IRC the ultimate load factors for checking ultimate moment and shear forces are as given below.

Check for Ultimate Moment of Resistance.

,

From table 2 of IS 1343-2012,

Maximum moment at mid span = 7257.02 kNm, which is less than .

Therefore the section is o.k.

= Area of tendon

= Characteristic tensile strength of tendon

= Tensile strength of tendon at failure

Check for ultimate shear.

As per IRC122 Cl 10.2.2

Net design shear force, V_{NS} = 2265 kN

Design yield stress of shear reinforcement, f_{ywd} $=347.83\ N/mm^2$

Design compressive stress in concrete, f_{cd}= 17.87 N/mm^2

Inclination of strut to Longitudinal reinforcement, θ= 45°

Maximum effective area of shear reinforcement, $A_{sw.max}$ $=925\ mm^2$

Area of reinforcement required for 10 mm dia bars @ 100mm c/c $=325\ mm^2$

Provide 4 legged Y10 @ 100 mm c/c as vertical stirrups at a distance 2.2m, provide

2 legged Y10 @ 150 mm c/c as vertical stirrups for remaining length

Longitudinal Bars in PSC Girder.

0.15 % of cross sectional area of web of the PSC beam is given

At support = 0.15/100x600x1950 = 1755 mm^2

Minimum diameter of bar and max spacing of bar is limited to 10mm and 200mm respectively for a severe exposure condition. Hence provide 44 nos 10mm dia bar on end section.

At mid span = 0.15/100x300x1650 = 742.50 mm^2

Minimum diameter of bar and max spacing of bar is limited to 10mm and 200mm respectively for a severe exposure condition. Hence provide 22 nos 10mm dia bar on mid span section

- **Vertical Bars in PSC Girder**.

Minimum vertical reinforcement required in the bulb = 0.18 % of plan area of bulb

0.18/100 x 600 x 1000 = 1080 mm^2

Hence provide 4L- Y10-200 mm c/c in the bulb as vertical portion

Design of End Block

Design for Vertical Mesh and Horizontal mesh.

End block design is carried out as per clause 13.5.1 of IRC 112-2011

Side of end block, $2Y_o$ = 350 mm

Side of loaded area, $2Y_{po}$ = 257 mm

Ratio, Y_{po}/Y_o = 0.734

From Table 13.1 of IRC 18-2000

F_{bs}/P_k = 0.11

P_k = Force in one cable considered

= 0.765x1860x 98.7 x 18

= 2527.92kN

Bursting force , F_{bs} = (F_{bs}/P_k) x P_k= 0.11x 2527.92

= 278.20 kN

Area of steel required to resist this tendon, $A_{st}= F_{bs}/ .87\ f_y$

= 278.20 E+3 / 0.87 x 415 = 770 mm²

This reinforcement is provided for a distance of 0.2Yo to 2Yo ie 35mm to 350m.

So provide 6 layered mesh of 10mm dia bars in both direction of cross section@ 100mm c/c.

Check for bearing pressure

Pre-stressing force at the jacking end = 2527.92kN

Bearing area for anchorage A_1 =257 x 257 = 66049 mm^2

Maximum Square area (without overlap) A2 =350 x 350 $=122500\ mm^2$

Permissible bearing stress

$=25.6 N/mm^2$

It is assumed that two-third of the force at anchorage is transmitted by bearing and adequate spiral reinforcement at anchorage end is to be provided at a suitable pitch.

Actual Bearing stress

< 25.60 N/mm^2

Actual bearing stress is less than allowable stress.

VII. CONCLUSIONS

Bridge reduces travel time and provide smoother traffic.Travel on the bridge results in saving in time, and also the loss of fuel for additional travel.Integral bridges increases the durability & seismic performances.Prestressing improving the performance under various service conditions. This bridge is designed as class 1 type structures without any tensile stress under service load, thus resulting in a crack – free structures.

VIII. REFERENCES

- Krishna Raju. N, “Prestressed Concrete”, IIIrd Edition 2006, Tata Mc Graw-hill Publishing Co.Pvt. Ltd.
- Krishna Raju. N,” Design of Bridge”, IIIrd Edition 1999, Oxford & IBH Publishing Co. Pvt. Ltd, 1988.
- IRC; 18 – 2000, 1”Design Criteria for Prestressed Concrete Road Bridges 1”(Post – Tensioned Concrete) Indian Roads Congress, New Delhi (section 8), pp1-61
- IRC; 6- 2000,” Standard Specifications and Code of Practice for Road Bridges”, Indian Roads Congress, New Delhi, pp1-54
- Johnson D. Victor, “Essentials of BridgeEngineering”, Oxford & IBH
- Krishnaraju, “Prestressed Concrete Bridges”, Tata McGraw Hill
- IS 456 – 2000 Plain and Reinforced Concrete - Code of Practice, Indian Standard,

INFRARED THERMOGRAPHY IN CIVIL ENGINEERING

Anand P

Graduate student

Sreepathy institute of management and technology,

Vavanoor, India

Amrutha M

Graduate student

Sreepathy institute of management and technology,

Vavanoor, India

Abstract:

Infrared thermography is a modern method to investigate structural condition and for damage assessment. Simply it can be defined as the science of the acquisition and analysis of data from non contact thermal imaging devices. Infrared thermography is a non destructive method therefore it can be used to evaluate the material without destroying it. Infrared cameras are provided for temperature measurement of buildings from inside as well as from outside. This method has wide range of applications in civil engineering. This paper gives a brief description on the theories and applications of infrared thermography.

INTRODUCTION:

Most materials absorb infrared radiation over a wide range of wavelengths, causing an increase in their temperature. All objects with a temperature greater than absolute zero emit infrared energy, and even glowing objects usually emit far more infrared energy than visible radiation. Thermal imaging is a technique for converting a thermal radiation pattern, which is invisible to the human eye, into a visual image. To achieve this, an infrared camera is used to measure and image the emitted infrared radiation from an object. Since this radiation is dependent upon the object surface temperature, it makes it possible for the camera to calculate and display this temperature. However, radiation measured by the camera does not only depend on the temperature of the object, but also its emissivity and its absorption by the atmosphere. Further radiation (reflected from the sun) may be introduced by the surroundings, which may be reflected on the object.

Infrared thermography and impulse radar have been used together on a number of occasions in the civil engineering industry for different applications— concrete structures and on highway bridges in the USA. Weil has shown that bridges, highway and airport pavement have been tested with both infrared and radar finding a variety of faults ranging from cracks on airport pavements to delaminations of concrete bridges. The technique of infrared thermography has been successfully applied in a number of other areas; e.g. to measure the conductive heat loss of infants in the medical industry, in the quality assessment and design of semi conductors, in the printing industry to determine when the ink is dry , in concrete structures in India , identification of buried mineshafts , identification of canal seepage as well as various other civil engineering applications . As well as many different applications of infrared thermography there are many different methods of using thermography; e.g. one-dimensional heat-flux sensing (which the majority of applications utilize), the quasi-steady technique and measuring heat transfer in wind tunnels.

THEORETICAL CONSIDERATIONS:

Infrared radiation is the electromagnetic radiation lies between visible light and microwaves, containing radiation with wavelengths ranging from 0.75 to 10 mm, Fig(1).This infrared region is often further subdivided into arbitrary sub-regions as shown in Table(1). It can be shown theoretically that peak radiation from a target at room temperature of 300 K occurs at a wavelength of 10 mm. Given that bridges in the field may be monitored at lower temperatures than room temperature, it can be seen that a long wavelength camera is required for structural surveys on bridges. This equates with the long wave or far infrared zone shown in Fig (1). The short wavelength camera is more applicable to a test environment with high temperature differences.

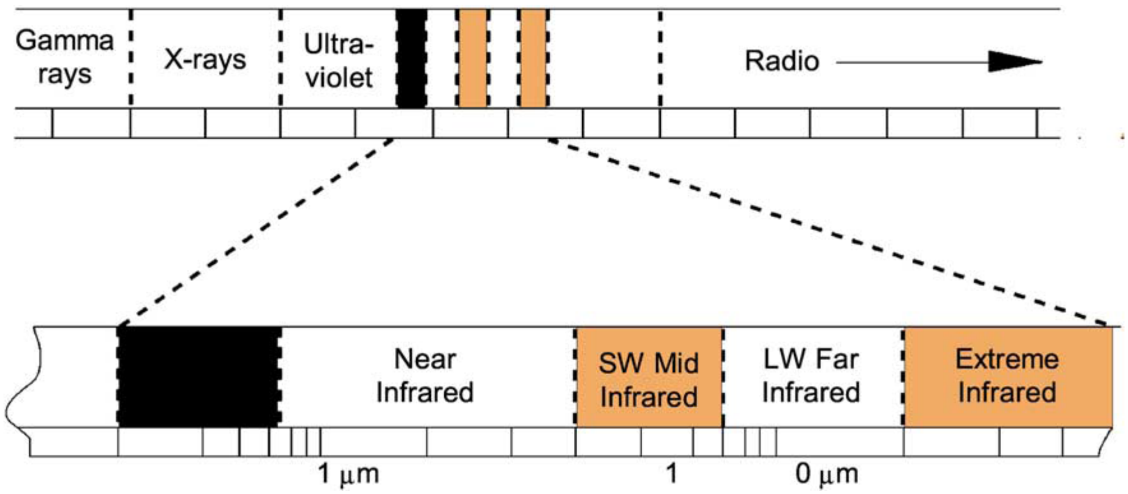


Fig.1.The electromagnetic spectrum

Sub region	Wavelength
Near infrared	0.75–3
Middle infrared	3–6
Far infrared	6–15
Extreme	15–100

Table 1: Infrared regions

Long wave cameras are able to detect small temperature differences. The camera captures the thermal information and relays it through the PC card interface to the laptop computer for data storage and processing. By measuring the emitted infrared radiation from an object this camera can measure differences in temperature down to 0.08 8C.Radiation is a function of an object's surface temperature, which makes it possible for the camera to calculate and display the temperature. The radiation measured by the camera does not depend only on the object surface temperature but is also a function of the emissivity. Emissivity is a measure of the efficiency of a surface to act as a radiator.

Other potential problems can occur when the object reflects radiation originating from the surroundings. Atmospheric absorption of radiation will also affect the measured temperature. There are three methods of heat transfer, conduction, convection and radiation. An infrared camera is only able to record the amount of radiated heat from an object. The rate of heat transfer through an object, which is dominated by convection and conduction depending on the object's material, determines how much energy can be radiated at the surface. One of the most important factors of each material when talking about heat transfer is the heat capacity of the material.

INFRARED CAMERA AND IMAGE PROCESSING:

Infrared camera senses the exiting thermal energy from the body, converts into temperature and displays thermal images. While the exact thermal properties are not always required to assess thermographs, the sources of radiation from the body help in correct assessment. A source of radiant thermal energy close to body may lead to incorrect interpretation of images. It should always be appreciated that infrared cameras senses only the radiant energy received from the surfaces and not the visible light reflected from the surfaces. Thermal images are vastly different from visual images and do not require visible light.

The infrared camera is a simple device and can be handled with usual precautions like an ordinary photographic camera. The images have to be focused and composed in the same way. The images are processed by software to yield thermal images. Thermal images appear as zones of different colours or shades depending upon the temperature selected. The bright regions in the thermal image indicate high temperature, while the dark region indicate the low temperatures and the intermediate regions are marked by colours ranging from white to black through yellow, orange, red and indigo.

PASSIVE & ACTIVE THERMOGRAPHY

The excitant energy from the surface of a body depends primarily on its temperature. The quality of thermal image depends on the variation in surface temperatures; the greater the contrast in temperatures, the better will be the images. Thermal images can usually be obtained under ambient conditions. When the body is heated by ambient conditions (solar radiation), it implies passive thermography.
Sometimes the body is heated by an external source to obtain temperature contrast. Such a process is known as active thermography. The former process is adopted while assessing large bodies, while active thermography is generally adopted in laboratory investigations.

PRACTICAL APPLICATION:

Thermal imagers offer an excellent means of making a qualitative determination of the temperature of a surface, but absolute temperature measurement is fraught with difficulties. This depends on many variables, such as the temperature of the surrounding materials, the atmospheric temperature, the ambient temperature, the weather, the object properties (i.e. the rate of conductivity, convection, the thermal heat capacity), stress-induced temperature change and absorption of infrared radiation. Consideration needs to be given to the fact that outdoors many factors alter the surface temperature of the object under investigation. The weather can have a major effect as sunlight may increase the temperature, wind may decrease the temperature of an object. Rain, which will lower the temperature of an object through both conductivity and evaporation, will also cause a change to the emissivity. However, any factor which highlights changes in temperature actually helps identify anomalies and features. The advantages of using a thermal imager to measure the surface temperature are: remote sensing, two-dimensional data acquisition, rapid response, non-contact, high resolution, large temperature range, post-processing versatility and portability. The use of thermal imaging to detect heat loss from a house is shown in Fig.2.

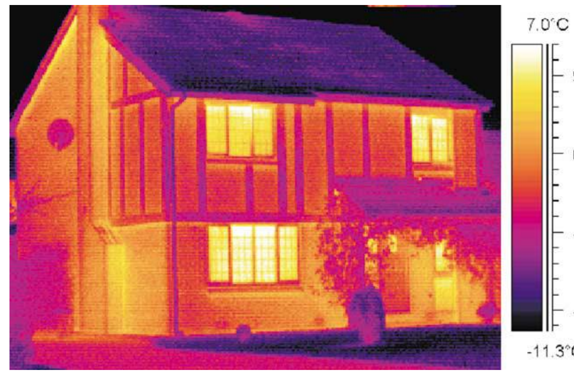


Fig (2). An infrared survey of a home can be used to highlight areas of excessive heat loss

The technique has numerous applications in condition assessment of structures, locating the source of distress, assessment of damage potential in concrete and masonry structures, identifying moisture ingress and flow through pipes. Thermal images are widely used in all branches of engineering including computer systems where it is especially used to locate components of excessive heat generation.

DEFECT DETECTION

The temperature profile for a non-defective area (a pixel or the mean value of a pixel cluster) is a continuous non-periodical signal that decays approximately as the square root of time. Figure 3 shows actual temperature profiles for a sound area (black continuous line) and for a 1 mm depth defective zone (black dotted line). A semi logarithmic scale is used to increase visibility at the first instants. The sound area temperature decreases until stabilization is reached (ambient temperature). After that moment, temperature changes are negligible.

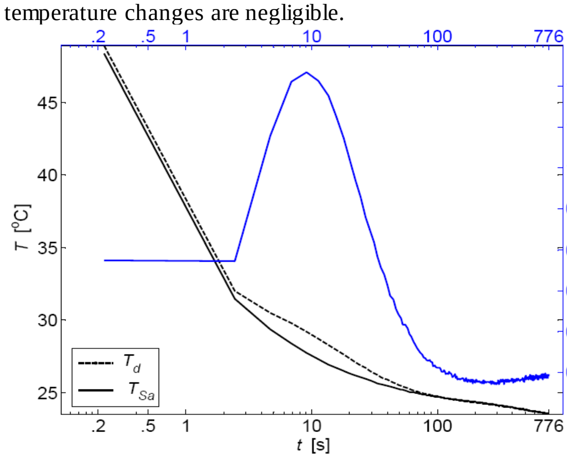


Figure3. Defect detection from temperature profiles

Temperature decay curves for both the defective and the sound areas behave similarly on the first instants after the application of heat since the heat front has not reached the defect yet. However, thermal effusivity e, which measures the material ability to exchange heat with its surroundings, is greater for sound material than for air, thus sound material acts better than air as thermal sink. Accordingly, once the thermal front has reached the defective area (air), surface temperature will be higher above the defective zone than above the sound area, from this moment to a given stabilization time.

The defective temperature profile would be inverted if the flaw had a higher thermal efusivity than the specimen material. Several data processing algorithms have been developed for defect characterization, i.e. determination of the size, depth and thermal resistance of a defect [8], [9]. Most of these techniques use thermal contrast calculations. The basic definition of thermal contrast is the Absolute Thermal Contrast, which measures the difference between defective and non-defective regions.

$$\Delta T = T_d - T_{sa} \quad (1)$$

Where T_d is the temperature of a defect, and T_{sa} is the temperature measured at a (non-defective) sound area Sa. Thermal contrast based analysis provide a good indication of defect characteristics (qualitative and quantitative) when working with relatively shallow defect in homogeneous materials and when non-uniformities at the surface are low (or can be corrected).

Non-uniform surface heating is an inherent source of uncertainty on active thermography. Even when a flat surface is inspected, several factors as heating source location, equipment aging, external heating or cooling sources, uneven optical properties of the surface, etc., will induce non-uniformities.

By using active infrared thermography and appropriate post processing techniques, detection of near-surface non homogeneities and common subsurface defects in typical structural elements is possible. The quantitative determination of their geometrical parameters and defect depth is the main objective for the practical problems like:

- locating and quantifying voids and honeycombing in concrete
- locating delaminations of plaster at concrete and masonry
- locating delaminations and voids behind tiles on concrete embedded in mortar
- assessment of bonding of carbon fibre reinforced laminates glued on concrete
- identifying poorly grouted ducts

ADVANTAGES & DISADVANTAGES OF IRT:

Advantages:

- It is a non contact type technique
- Fast, reliable and accurate output
- A large surface area can be scanned in no time
- Presented in visual and digital form
- Software back up for image processing and analysis
- Requires very little skill for monitoring

Disadvantages:

- Cost of instrument is relatively high
- Unable to detect the inside temperature if the medium is separated by glass/polythene material

CONCLUSION

By using passive infrared thermography, defects in concrete structures can be inspected using only an infrared camera. This method, however, strongly depends on weather conditions since it requires the presence of sunlight or an increase in air temperature, it cannot be used, then, when it is overcast or raining. The most important result from presented research is that simulated defects can be detected by using passive infrared thermography under certain conditions and only few of the existing defects are visible.

There is a need to develop new quantitative non-destructive testing techniques for delaminations defects in concrete structures. Some techniques already in use in the field of aerospace industries and mechanical engineering can be applied to civil engineering problems respecting the differences in thermal properties and the homogeneities of materials. The purpose of this paper was to present new active techniques of infrared thermography that could be used for detection.

REFERENCES:

1. D.S Prakash Rao “Infrared thermography & its applications in civil engineering” *The Indian concrete journal*, volume 9, May 2008, pp.41-50
2. Clark, M. R., McCann, D. M. and Forde, M. C., "Application of Infrared thermography to the non-destructive testing of concrete and masonry bridges", *NDT &E International*, volume 36, 2003, pp.265-275.

INSPECTION & REPAIR OF CONCRETE BRIDGES

RESHMA THILAK
S8 – Civil Engineering
Sreepathy Institute of Management and Technology,
Vavanoor, India

Ms. ANJALI P.
S8 – Civil Engineering
Sreepathy Institute of Management and Technology,
Vavanoor, India

ABSTRACT

Maintenance of bridges is equally important as the construction of bridges. For proper maintenance proper inspection is also required. The bridge inspection process starts with the bridge inspectors reviewing the previous bridge inspection report and planning the inspection. The inspectors identify areas where defects were found in previous inspections. This allows them to determine if the defects previously identified have been repaired or have increased in size and severity and also helps them to adopt proper repairing methods.

For the inspection of bridges proper knowledge about different defects are necessary. By knowing the defects selection of appropriate equipments for measuring those defects can be easily selected. Methods of access to the unreachable parts of the bridges such as bottom and sides of deck slab are also important.

The seminar report gives detailed procedure of inspection of concrete bridges including the types of inspection, parameters to be inspected, various defects, equipments used for inspection, methods of access, and safety precautions during bridge inspection and various maintenance and repair works adopted for concrete bridges.

I. INTRODUCTION:

A bridge is defined as a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads.

The existing bridges in India are more than 50 years and were designed for less volume of traffic, slower speed and lighter loads. The various factors have resulted in deterioration of bridges and the need for their maintenance, rehabilitation or replacement has increased manifold. The normal aging of bridges and other elevated highway structures coupled with large increases in vehicular traffic have made it very important that elevated highway structures receive timely inspections. Thus, it has become essential to have an effective system for inspection of bridges at faster speed and regular intervals. Bridge inspection is a critical task to ensure the safety and serviceability of bridges.

Inspection is to be done to identify and measure the deterioration which may be caused by applied loads and other factors i.e. dead load, live load, and wind load and physical and chemical influences of climate apart of the natural or accidental calamities. Inspection can also be used to identify any built - in – imperfections and thus proper maintenance and repair works can be adopted and it also help to increase the useful life of bridges.

II. TYPES OF INSPECTION:

A number of different types of inspections have been developed to address specific needs. This section will identify and describe the inspection types used.

A. Initial Inspection

The first inspection of a bridge as it becomes a part of the bridge inventory to provide all Structure Inventory and Appraisal data and other relevant data and to determine baseline structural conditions.

B. Routine Inspection

Regularly scheduled inspection or condition assessment that consists of observations and/or measurements needed to determine the physical and functional condition of the bridge.

C. Detailed Inspection

This is a technical inspection during which thorough examination of each and every component of the bridge and its super structure is carried out with the help of equipments.

D. Underwater Inspection

Inspection of the underwater portion of a bridge substructure and the surrounding channel, which cannot be inspected visually at low water by wading or probing, generally requires diving or other appropriate techniques.

E. Special Inspections

This inspection is done for specified bridge which needs a inspection due to some extraordinary reasons i.e. early steel bridges, bridge damaged due to accidents or natural calamities, bridge to be undergone heavy repairs etc., bridge showing built-in-imperfections or heavy deterioration etc.

F. In-depth Inspections

A close-up inspection of one or more members above or below the water level to identify any deficiencies not readily detectable using routine inspection procedures; hands-on inspection may be necessary at some locations.

III. IMPORTANT DEFECTS IN CONCRETE BRIDGES

RCC/Concrete bridges are now being widely adopted. Even in case of newly constructed box girders, composite girders, no inspection and maintenance is being carried out by field officers/staff, which has become a matter of serious concern. Concrete components may show following signs of visual damage which should be looked for-

A. Cracks

Cracking is a common manifestation of concrete deterioration which can be caused by a variety of factors. Cracks which are found in bridges and overpasses are generally described as structural or non structural. Structural cracks are caused by both dead and live load stresses, which can lead to eventual failure of the structure. Flexure structural cracks are vertical and begin in areas of maximum tension or moment. Shear structural cracks are diagonal and are usually found in the web of a member. They may begin at the bottom and move diagonally toward the centre of the member.

Non structural cracks can be caused by thermal expansion and contraction of concrete, contraction of the concrete during the curing process, or temperature gradients within massive sections of concrete. Also, the presence of rust stains around non structural cracks normally indicates corrosion of steel reinforcements in a concrete member. These cracks generally do not affect the load-carrying ability of a member, but may lead to higher susceptibility to other types of deterioration.

B. Scaling

Gradual loss of surface mortar and aggregate over an area is known as scaling. Scaling is classified as light, medium, heavy, and severe. Light scale is the loss of surface mortar up to ¼ inch deep exposing coarse aggregates. Medium scale is the loss of surface mortar from ¼ inch to ½ inch deep with mortar loss between the coarse aggregates. Heavy scale is the loss of surface mortar from ½ inch deep to 1 inch deep clearly exposing coarse aggregates. Severe scale is the loss of surface mortar greater than 1 inch deep where coarse aggregate particles are lost and reinforcing steel is exposed.

C. Spalling

Spalling occurs when a delaminated area completely separates from a member. The roughly circular or oval depression left is known as a spall. Friction from thermal movement can also cause spalling in addition to corrosion.

D. Delamination

Delamination is the separating of concrete layers at or near the outermost layer of reinforcing steel. Delamination is caused by the expansion of corroding reinforcing steel and can lead to severe cracking.

E. Efflorescence

Efflorescence is the result of hydrolysis of cement paste components in concrete. It is indicated by the presence of white deposits on the concrete, usually on the underside of bridges and overpasses. Efflorescence indicates that the water used in the concrete mixing process was contaminated.

F. Construction defects

This includes consolidation issues such as rock pockets, honeycomb voids, bug holes, and sand streaks which may result from improper vibration, dry mix, over-watered mix, improper rebar spacing, or improper aggregate selection.

G. Pop outs

Pop-outs are a result of alkali-silica reactions taking place in concrete. Conical fragments break out of the surface of the concrete leaving small holes. Shattered aggregate particles will usually be found at the bottom of the hole.

H. Wear

Vehicular traffic causes wear on bridge decks throughout the life of the structure.

IV. INSPECTION PROCEDURE:

The inspection should be such as to discover all indications of damage, such as cracks, fissures or spalling of concrete, and unexpected deflections or deformations. Such deformations do not necessarily cause cracking immediately but cracks may develop later as a result of them. Other aspects to be noted are adequacy of clearance and drainage arrangements, and signs of damage by impact from rolling stock

A. For Cracking

- Record its location, width & length, type & pattern, behaviour under load etc…
- Check whether it is active or dormant
- Mark the crack
- Analyse each crack
- Measurement of crack

B. Spalling & Scaling

- Record the area, depth & location
- Record the condition of reinforcement
- Record the level of scaling

C. Bearings

- Record the condition of bearings
- Analyse the behaviours with respect to movement recorded
- If there is any crushing/ damage in concrete bearing then examine the behaviour under the load.

D. Drainage arrangement

- Check water stains on slabs & girders
- Check accumulation of debris around inlet

- Ensure that water from outlets is not discharged at a place which is detrimental to any components
- Inspect run off pipes for damage or leakage

E. Locations to be specially looked for defects

The following locations to be specially inspected for the defects mentioned against them

- Top of deck slab
- Bottom of deck slab
- Anchorage zones
- Joints in segmental construction
- Expansion joint
- Drainage pipes & Vent holes

V. INSPECTION EQUIPMENTS:

Following equipments are required for thorough inspection of various elements of bridges

- 30m Steel tape
- Plumb bob
- Chipping hammer
- Magnifying glass
- Binoculars
- Straight edge
- Feeler gauge (0.1 to 5mm)
- Measuring microscope
- Nylon chord
- 15cm steel scale
- Mirror(10 x 15cm)
- Torch light
- Thermometer
- Pocket knife
- Camera with flash

VI. METHOD OF ACCESS:

The two primary methods of gaining access too hard to reach areas of bridge are access equipments and access vehicles. Common access equipments include ladders, rigging etc… The time saved, however, is normally offset by the higher costs associated with opening access vehicles

A. Types of access equipments

The purpose of access equipment is to position the inspector close enough to the bridge components so that a "hands-on" inspection can be performed. The following are some of the most common forms of access equipment used in bridge inspection.

1.Ladders

Ladders are used for inspecting the underside of a bridge or for inspecting substructure units. However, a ladder is used only for those portions of the bridge that can be reached safely, without undue leaning or reaching. The proper length of the ladder is determined by using it at a four vertical to one horizontal angle. When set up at the proper angle (1 horizontal to 4 vertical), the inspector is able to reach out horizontally, grasp the rung while keeping his or her feet at the base of the ladder.

2. Rigging

It consists of cables & platforms. Used when ladders or other equipments cannot be used. It do not interfere traffic. Used when bridge do not have the capacity to support inspection vehicle

3.Boats or Barges

It provides access to structures over water and can be temporarily anchored in one place to provide a platform for underwater inspections.

4.Floats

It is a platform hung by ropes and is used when inspector have to stay at a particular location for a long time

5. Bosun chairs/Rappelling

Bosun (or boatswain) chairs are suspended with a rope and can carry one inspector at a time. They can be raised and lowered with block and tackle devices. Rappelling is a similar access method to the Bosun chair but utilizes different equipment and techniques. However, both methods require the use of independent safety lines.

6. Inspection Robots

Currently, efforts are being made for robots to be used for inspection purposes. Though still early in the development stage, robots may prove to be an important addition to the inspector's access equipment. Although a robot can never replace a qualified inspector, it can provide information that may not be visible to the human eye. A robot equipped with sonar capabilities can detect internal flaws in bridge members. Also, a robot can be used in situations that are too difficult to reach or extremely dangerous for a human.

B. Types of access vehicles

There are many types of vehicles available to assist the inspector in gaining access for "hands-on" inspection of bridge members The following are some of the most common types of access vehicles used in bridge inspection

1. Manlift

It consists of a bucket holding inspectors which is attached to a hydraulic boom. It has a vertical reach of 40 feet to 170 feet

2. Scissor lift

It is used when there is low clearance between bridge & under passing roadway. It has a vertical reach of 20 feet.

3. Bucket trucks

A bucket truck is similar to a manlift. However, a bucket truck can be driven on a highway, and the inspector controls bucket movement. As with the manlift, a bucket truck needs to be used on fairly level terrain.

4. Under bridge inspection vehicle

An under bridge inspection vehicle is a specialized bucket truck with an articulated boom designed to reach under the superstructure while parked on the bridge deck. Usually the third boom has the capacity for extending and retracting, allowing for greater reach under a structure. Some of the larger under bridge inspection vehicles have four booms, allowing an even greater reach.

VII. SAFETY PRECAUTIONS:

While inspecting bridges one should adopt certain safety measures which are listed below

- Wear suitable dress.
- Keep clothing's & shoe free from grease
- Platforms should be free from slippery substances
- Keep trolley and other equipments properly
- Say no to liquor or any other sedative medicine.
- Follow all operating rules and follow the guide lines.
- Be very careful while walking through footpaths
- No chit chatting and fun on Inspection.

VIII. BRIDGE REPAIR:

In repairing deteriorated concrete bridges, the primary objective is to restore the structure to its original shape and condition by using a material that will ensure structural integrity, durability, and composite behaviour, while matching the existing concrete in colour and appearance. The repair material should be at least as strong and durable as the existing concrete. The cost factor has to be considered carefully before specifying any particular repairing material.

A. Scaling & spalling

Do patching, coating & shotcreting

B. Voids

Repair methods are preplaced aggregates, shotcrete & patching

C. Cracks

Do pressure injection, shotcrete, patching, grinding, strengthening etc

D. Delamination

Do pressure grouting

IX. CONCLUSION

The main safety risks related to bridge infrastructure are accidents, such as those caused by concrete falling, or parts of a bridge structure failing to perform their intended function of providing adequate protection to the vehicles travelling on the structure. To provide the necessary bridge bearing capacity and traffic safety in the conditions with limited financing the bridge engineers have to concentrate on bridge inspection and repairs. The main deficiencies of concrete bridges are catastrophic failure, structural damage, premature aging, and construction and design defects. Information collected from detailed inspections gives the main causes of these problems.

In order to overcome these problems of concrete bridges proper repair techniques should be adopted. Timely inspection and repairs can systematically control status of defect formation and essentially eliminate them. The solutions thus adopted help to eliminate outstanding problems and their potential causes currently occurring on concrete structures and helps to enhance physical quality of bridges.

X. REFERENCES

- Ahmed Al-Ostaz, "*Diagnostic evaluation and repair of deteriorated Concrete bridges*", Department of civil engineering, University of Mississippi, December 2009.
- Alok Sarkar, "*Repair of concrete bridges",* The Indian Concrete Journal, June 2008.
- Clayton Bennett (State Bridge Inspection Engineer)*"Bridge structure, maintenance and rehabilitation Repair manual",* office of structural design bridge maintenance unit, Georgia department of transportation, June 2012
- Ilmars Jurka *"Experience of bridge maintenance and Reconstruction in Latvia"* , Head of Bridge Department, Latvian Road Administration, May 2010
- Gary L. Bowling, Jeff Swanstrom, Steve Tuttle, "*Bridge Inspection Manual*", Oregon department of transportation, Jan 2012

Magnetic Water Technology

Ms. Minnu Unni
Civil Engineering Department
Sreepathy Institute of Management and Technology
Vavanoor, India
chinnuclassics93@gmail.com

Mr. Abhilash P. P.
Assistant Professor, Civil Engineering Department
Sreepathy Institute of Management and Technology
Vavanoor, India
abhiaie@gmail.com

***Abstract* -The objective of this article is to present a new technology to improve the properties of concrete called Magnetic water technology. In this technology, by passing water through a magnetic field, some of its physical properties change and, as a result of such changes, the number of molecules in the water cluster decrease, which causes a decrease in the water surface tension. Using magnetized water in concrete mixtures causes an improvement in the workability and compressive strength of concrete. Also, this processed water causes a reduction in the cement content required for the specified compressive strength value. This paper includes details of magnetic device, magnetization process and the laboratory experiments conducted. Finally the test results showed that concrete made with magnetic water has higher slump value, compressive strength and splitting strength and with the same slump and compressive strength, cement content can be reduced.**

Key words- **Magnetic water, Magnetic device, Hydration process**

I. INTRODUCTION

Increasing the compressive strength of concrete is an aim which most concrete technologists are looking for, using various methods like fiber reinforcement in concrete mixture and usage of certain admixtures including super plasticizers to produce high strength concrete. One such technique is using magnetic water for manufacturing of concrete. In this technology, by passing water through a magnetic field, some of its physical properties change which improves and enhances properties of concrete.

Magnetic water treatment machine was first invented in 1945 by a distinguished Belgian engineer. This machine which is currently utilized in more than fifty countries around the world such as America and Russia was practically introduced to the market and as a result of a series of persistent and continuous studies.This machine simply works based on the electromagnetic induction principle which was introduced by Mickeal Faraday in 1832. Water passing through this machine undergoes the magnetic energy present there, which influences the colliding particles, calcium carbonate molecules(CaCO3), salts and other saline in water and changes their physical and electrical properties and creates a particular pattern. This change in the electron pattern in ions leads to a lack of activity in forming compositions and no precipitation occurs. Also, magnetic energy reduces the surface tension of water by 10%. However, because of such changes, no suitable environment is provided for the formation of viscous deposits (adherence of calcium crystals and other substances) and in this way magnetic water with its unique and special properties is produced.

Magnetic devices include one or more permanent magnets, which induce changes and effects on ions and water molecule clusters passing through its magnetic field. A magnetic field has a considerable effect on clusters of water molecules and causes the decrease of such a mass from 13 molecules to 5 or 6 molecules. Such a decrease of molecules causes more participation of water molecules in the cement hydration reaction. Also, when water is mixed with cement, cement particles are surrounded by water molecule clusters. In the case of magnetic water in which the clusters have a smaller size and lower density, the thickness of the water layer around the cement particle is thinner than in the case of normal water. This fact results in a decrease in water demand for concrete mixing and, subsequently, in reducing the w/c ratio, which has positive effects on hardened concrete properties, such as strength, durability, etc.

A. Scope of the study

Concrete based on Portland Cement (PC) is extensively used construction material, given that it is more economical (compared to metals and other materials). One of the negative aspects of PC is that its fabrication generates CO_2 through calcination of raw materials and fuel consumption. It is calculated that 1 ton of PC generates 1 ton of CO_2 [4]. This seminar paper presents the method of improving strength of given grade of concrete by reducing the usage of cement in a mix without effecting the other properties of concrete by replacing normal water with magnetic water for mixing of ingredients in concrete.

II. MAGNETIC WATER (MW)

A substance is said to be magnetized when its constituent molecules or structural elements can be aligned in a definite direction by the influence of an external magnetic field. In fact water, like most molecules is diamagnetic. Diamagnetism refers to substances that are magnetized in a way opposite to the direction of magnetic field, having pair-up electrons which cancel each other's magnetic moment because the two electrons in a pair-up rotate opposite to each other. In actual case water molecules are bonded as an isolated triangle with its upper angle 105º.When water is subjected to a magnetic field, the water molecules will arrange in one direction. Thus the viscosity of magnetic water is less than viscosity of normal water, which improves some properties in concrete.

A. Magnetic device

The type of magnet which is used in many household appliances, automobiles, and industrial machines. This type of magnet can be used to produce a magnetic field and has the advantage control of the magnetic field strength by controlling the voltage of the electric current passed through the coil wire However, the type of magnetizer used in the first stage is known as permanent magnets, where magnet strength is a result of mutual alignment of very small magnetic fields produced by each atom in the magnet. Permanent magnets are composed mainly of ferromagnetic materials such as iron, cobalt, and nickel. The magnetic field is then a result of charged particles. The Ampere's function used to find the magnetic field inside the coil is as follows,

$$\beta = \mu o\ (N \times I)/L$$

The strength of a magnet is given by its magnetic flux density, which is measured in unit of Gauss, (1 Gauss = 10^{-4} Teslas = 100 µT. Unit for 1 Tesla is Weber/m^2. The magnetizer is a set of permanent series of ring magnet materials arranged in a certain manner in a Poly Venial Chloride (PVC) body to form of magnetic field with length greater than its radius. Fig. 5.6 shows the water magnetizer. Its output is up to 90 m^3/hr., it is made of PVC body, and is used without preliminary filtration of water with high salt content.

Fig. 2.1 Permanent magnets field (water magnetizer)

a) Water treatment

The water was simply treated by passing it through magnetic field (magnetizer). MW can be prepared by passing it through magnetic field, using an im-merseable pump to circulate the water through the magnetic field for 45 min, with a velocity of 9 m³/hr. As a result the surface tension of water decreased by 7.4 mN/m.

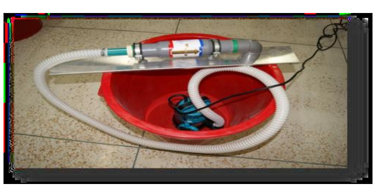


Fig. 2.2 Immerse-able pump (Magnetizer)

b) Requirements of standard device

- Should made by super conductivity magnets.
- Should produce enough strength of magnetic field, so that magnetic lines of force of magnet can penetrate over total water through wise arrangement.
- Weight and mass of pure water should be suitable.
- At the same time after pure water is magnetized, we should inject immediately into sample baths of instrument to measure their properties.

B. Magnetic water preparation

Magnetic water can be prepared by retaining water in a glass beaker over a round magnet. The Magnetic water is obtained by placing the beaker filled with water over the magnets for a specific period. During this time magnetic field penetrates through the glass into the water, which absorbs the magnetism and this magnetized water is used for making concrete. Also it can be prepared by pouring water through magnetic device.

III. HYDRATION OF CEMENT

Hydration of cement using normal water and magnetized water can be explained through a comparison as shown in table 3.1.

Table 3.1 Hydration of Cement

Hydration with Normal water	Hydration with Magnetized water
Water molecule cluster have larger size	Water molecule cluster have smaller size
Have higher density	Have lower density
Thick layer of water around cement particle	Thin layer of water around cement particle
Increase in water demand	Decrease in water demand
Increased w/c ratio	Decreased w/c ratio
Hydration products formed hinders further hydration and prevent development of mechanical strength of concrete	Positive effects on hardened concrete properties such as strength, durability etc.

IV. EXPERIMENTAL PROGRAMME

Several tests on concrete mixes such as workability, compressive strength, and splitting strength tests, prepared using magnetized water were undertaken in the laboratory. Moreover, the effect of magnetized water of different field strengths on the engineering properties of fresh concrete is examined.

A. Materials used

- Cement: Geelong general purpose cement(G.P)
- Fine and coarse aggregate: Red sand & crushed gravel, nominal sizes of gravel were 7, 10, & 20m
- Water magnetization unit: Two magnetic devices were designed which create magnetic strengths of 6000 Gauss & 9000 Gauss

B. Concrete mixes

In order to investigate the effect of using MW, three concrete mixes were prepared with different mix proportions: 1: 1.87: 3.37 mix A; 1: 1.5: 3 mix B; and 1: 1.7: 2.54 mix C. These three mixes were prepared first with normal water and the same mixes were also prepared with magnetized water.

C. Experimental methods

A slump test according to ASTM C-143-90a was undertaken on the concrete mixture to ensure that it was within the design value and to study the effect of magnetic water replacement on the workability of concrete. The concrete was then poured into standard cylinders 100mm in diameter and 200mm long, and compacted using a vibrating table. After testing the cured specimens, the effect of magnetic water replacement on the compressive and splitting strengths of concrete are studied.

a) Methodology

For finding out the concrete workability, slump tests were carried**.** Magnetized and tap water were used for concrete mixing .Concrete was poured into the standard cylinders 100 mm in diameter and 200 mm long and compacted using vibrating table. Specimens were demoulded after 24 hours & cured in water. The following tests were carried out –

(i) Compressive strength test

- Samples were tested using compressive testing machine
- Carried out according to ASTM C39, using loading rate of 2.36 kN/s

(ii) Splitting strength test

- Carried out according to ASTM C49-96, using loading rate of 0.63 kN/s

V. RESULTS AND DISCUSSION

The concrete sample prepared with MW achieved better performance, as shown by the comparison of concrete properties of the specimens prepared with normal water and those prepared with MW. The properties of concrete in its fresh and hardened states were compared to evaluate the effect of using MW.

A. Slump of fresh concrete with magnetic field intensity

Slump tests were conducted on all concrete mixes prepared with either tap or magnetized water, and the results were obtained. The slump values increase by using the magnetic field as in, or when comparing between Mixes A, B, C produced with normal water and Mixes A1, B1, C1 produced with magnetized water, also these values increases by increasing the magnetic field intensities, as in or between the Mixes A1, B1, C1 and Mixes A2, B2, C2. It is shown in Fig. 5.1. An increase between 40 to 90 % was achieved in slump when magnetized water was used.

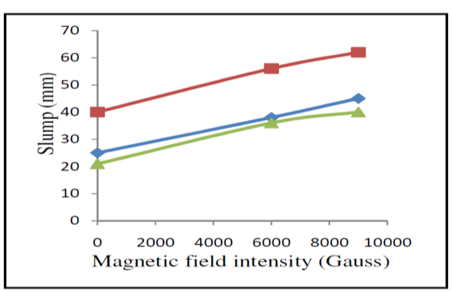


Fig. 5.1 Effect of magnetic field intensity on the slump

The reason for this phenomenon can be explained as follows. Magnetic devices include one or more permanent magnets, which induce changes and effects on ions and water molecule clusters passing through its magnetic field.

B. *Slump of fresh concrete with different cement contents*

The slump values at the magnetic intensity 9000 Gauss, increases with increasing the amount of cement, in spite of equal proportion of water-cement ratio. From the Fig 5.2, it can be concluded that the effect of the magnetic field increases at higher cement content and w/c ratio, and the slump of the samples improves.

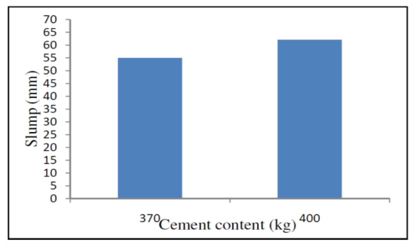


Fig. 5.2 Effect of cement content on the slump at 9000 Gauss

C. Compressive strength of concrete

The compressive strengths at 7, 14 and 28 days were recorded for different concrete mixes using normal water and magnetized water. The values for the compressive strength of the concrete mixes fabricated with magnetized water at 7, 14 and 28 days of age were higher than those for the concrete mixes fabricated with tap water. The percentages of increase of compressive strength at all ages ranged from 10% to 19%.

To date, the most accepted hypothesis is that under the action of magnetic field, the clusters or molecules groups of tap water which have been linked together with hydrogen bonds will be cut or damaged. Consequently, it will break into groups of small molecules or individual water molecules. Changes in the connections between molecules of magnetic water can lead to physical properties changes in magnetic water, such as surface tension.

Magnetic water molecules can easily penetrate the cement particles, allowing a more complete hydration process to occur and enhancing the mechanical strength of concrete. Fig 5.3 shows 28 days compressive strength of concrete with different magnetic field intensity for different mixes.

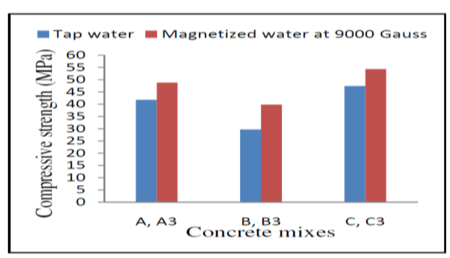


Fig. 5.3 Compressive strength (28 days)

D. Splitting tensile strength

Generally, higher values of splitting tensile strength were recorded for the concrete mixes produced with magnetized water when compared with the concrete mixes prepared with tap water, which may be attributed to the better hydration process between magnetized water and cement. The percentages of increase were in the range of 9% to 18%.

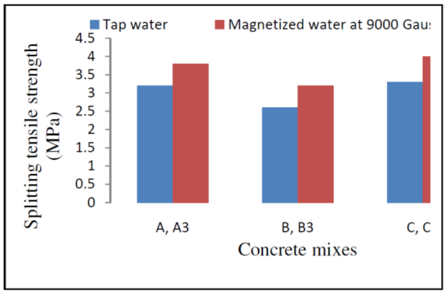


Fig. 5.4 Splitting tensile strength at 28 days

Following conclusions can be drawn from test results;

1. Using 9000 Gauss magnetic field intensity is the best treatment of water to make concrete
2. Can increase the workability of concrete without adding access water or any other materials
3. Magnetic water has lower surface tension
 - can increase the activity of the cement
 - can make the cement hydration more complete and the structure more compact
4. The use of magnetic water increases workability and strength
5. The compressive and splitting tensile strengths of concrete samples increased by about 20% compared to tap water
6. Allow a reduction of the cement content of concrete mixes about 7.5% without affecting the concrete compressive strength.

VI. CONCLUSION

Magnetic water technology is a good technology to improve concrete properties In this technology water passes through magnetic field which causes breakdown of water molecule clusters, which allow easy penetration into cementatous grains The technology lead to effective hydration which gave improvement of concrete durability. Magnetic water molecules can easily enter the cement grains, thus it can increase the workability of concrete mixtures. The compressive and splitting tensile strengths of concrete samples prepared with magnetic water with the same mixture proportions, increased by about 20% compared to those prepared with ordinary water. It also allow a reduction of the cement content of concrete mixes about 7.5% without affecting the concrete compressive strength. Overall, magnetic water increases the efficiency of concrete.

ACKNOWLDGEMENT

First of all I thank the almighty for giving me an opportunity to present the seminar with strength and courage. I thank Dr. S. P. Subramanian, Principal and Mr. Sudheer K. V., The Head of Civil Engineering Department of Sreepathy Institute of Management and Technology, for permitting me to conduct the seminar. I also at the outmost thank and express my profound gratitude to my seminar guide Mr. Abhilash P. P., Assistant Professor in Civil Engineering Department, for his inspiring assistance, encouragement and useful guidance.

REFERENCES

[1] M Gholizadeh and H Arabshahi (2011):"The Effect of Magnetic Water on Strength Parameters 0f Concrete", Journal of Engineering and Technology Research, Vol. 3, No. 3, March 2011, pp. 77-81.

[2] Ali S. Faris, et al. (2014): "Implementation of Magnetized Water to Improve the Properties of Concrete", International Journal of Civil Engineering and Technology (IJCIET), Vol. 5, No. 10, October 2014, pp. 43-57.

[3] Yasser R. Tawfic and Wael Abdelmoez (2013): "The Influence of Water Magnetization on Fresh and Hardened Concrete Properties", International Journal of Civil Engineering and Technology (IJCIET), Vol. 4, No. 6, November – December 2013, pp. 31-43.

[4] B. Siva Konda Reddy, et al. (2014): "Influence of Magnetic Water on Strength Properties of Concrete", Indian Journal of Science and Technology, Vol.7, No.1, January 2014, pp.14–18.

[5] B. Siva Konda Reddy, et al. (2013): "Effect of Magnetic Field Exposure Time on Workability and Compressive Strength of Magnetic Water Concrete" International Journal of Advanced Engineering Technology, Vol.4, No. 3, July-September 2013, pp.120-122.

[6] Ali Shynier, et al. (2013): "Improving Some of Mechanical Properties of Concrete by

Magnetic Water Technology", Journal of Cement and Concrete Research, Vol.4, No. 3, pp. 599-605.

[7] Hassan Karam and Osama Al-Shamali (2012): "Effect of Using Magnetized Water on Concrete Properties", Third International Conference on Sustainable Construction Materials and Technologies, Kuwait Institute for Scientific Research, Kuwait, 22th – 25th September 2012, pp. 559-564.

[8] Saddam M. Ahmed (2009): "Effect of Magnetic Water on Engineering Properties of Concrete" International Journal of Chemistry, Vol.17, No.1 February. 2009, pp. 30-35.

MONOLITHIC DOME

Ms. Jisha Dev V.P & Ms.Swathy Mohan K.M
Civil Engineering Department
Sreepathy Institute of Management and Technology,
Vavanoor, India

Mr. Adnan N.A
Assistant Professor, Civil Engineering Department
Sreepathy Institute of Management and Technology,
Vavanoor,India

Abstract:The objective of this article is to present a new method of technology to improve field of construction. In this Monolithic Dome structures we Introduce a new technology that maintain the appearance and strong and durability of building structures. It is more energy efficient practice compare to other technology. This paper includes the details of the construction process, profiles and main features and advantages.

1. INTRODUCTION

A monolithic dome (from Greek mono- and -lithic, meaning "one stone") is a structure cast in a one-piece form. The form may be permanent or temporary and may or may not remain part of the finished structure. Forms have been made using nearly every common structural material. A monolithic dome may be defined as a thin shell generated by the revolution of a regular curve about one of its axis. The shape of the dome depends upon the type of the curve and the direction of the axis of revolution.

Monolithic Domes are the most energy efficient and safest buildings that can be built and that can be designed for many uses. The spherical sections of the dome offer minimal surface area for the volume they contain, so there is less surface for heat transfer with the outside air. The construction of monolithic dome with proper earth sheltering will withstand bomb blasts more effectively than conventional structures. The strength and stability of domes make them virtually immune to climatic catastrophe, or earthquakes, as well as to fire, or corrosion hazards. Many schools now conduct their classes in Monolithic Domes. Some are designated as tornado shelters. Others have Monolithic Dome gymnasiums, auditoriums, multipurpose centers, libraries, cafeterias, etc. Now there are monolithic domes throughout the United States and the world- built north of the Artic Circle in Murmansk, Russia, to the Equator in Indonesia. Churches, schools, storage buildings, homes, and recreational centers all use monolithic domes. Sizes range from very small 8 foot (2.5m) to very large 260 foot (80m) diameter.

2. REASONS FOR MONOLITHIC DOME

2.1 Highly energy-efficient

The shape of the Monolithic Dome is one of the reasons for its energy efficiency. There is less surface area per square foot to heat or cool compared to the square or rectangular building. However, the materials used in its construction are a more important component of energy savings that result in these round structures. Polyurethane foam, one of the best insulating products available today, accounts for a large part of the Monolithic Dome's energy efficiency. Because the foam protects the concrete, a thermal mass provides superior energy efficiency. When the interior of the dome is heated or cooled the concrete warms up or cools off, then maintains that temperature for a long period, and radiates that temperature back into the dome's interior. This translates to a savings on average of 30-50% vs typical construction methods to heat and cool a Monolithic Dome.

2.2 Lower Construction & Maintenance Costs

Generally, the construction of a Monolithic Dome costs equal to or less than that of a conventional structure of a similar size. In 2000 and 2001, construction costs for Monolithic Dome schools finished in the upper $70s and low $80s per sq ft. Lower total cost of ownership it also includes heating and cooling bills. Polyurethane is one of the best known materials for insulation. A high insulating factor is one of the reasons for the particular grade of polyurethane used on the dome. Beneath the foam, the concrete layer retains and moderates fluctuations of the interior temperature. Cost reductions in energy bills of 50% to 75% are common among Monolithic Dome owners, compared to the equivalent size conventional home.

2.3 Longevity - Life Span Measured in Centuries

The lifetime of a Monolithic Dome is measured in centuries. Over the years as needs change, a Monolithic Dome home, church or school may need remodeling but not replacement. In most cases, the clear-span interior of the dome makes remodeling relatively simple. The protective shell will prevent most decay and damage from the elements over time compared to normal structures.

2.4 Survivability

In the FEMA manual titled Design and Construction Guidance for Community Shelters, near-absolute protection means that, based on the knowledge of tornadoes and hurricanes, the occupants of a shelter built according to this guidance will be protected from injury or death. In short Monolithic Domes can offer near absolute protection from natural disasters such as tornadoes, hurricanes and earthquakes. Monolithic Dome construction meets and exceeds FEMA's criteria. They meet or exceed FEMA's standards for providing near-absolute protection. Monolithic

2.5 Design Abundance and Flexibility

In size, Monolithic Dome homes range from cozy-cute to palatial and include everything in between. So you can plan for just what you need or all that you want. As a Monolithic

Dome, your dream home can be single-story or multi-story. It could consist of one dome or two or more interconnected domes. It could sport a basement, loft or indoor swimming pool. It could be earth-bermed or totally underground. It can complement its natural environment whether that’s a mountain, a beach, a forest, a ranch or an urban development. And its interior and exterior can be enhanced, embellished and decorated following the same design principles that apply to traditional homes.

2.6 Green Buildings

People admire Monolithic Domes for many different reasons. Some like their graceful, curved lines. Others admire their open, clear-span interiors. Still others become fascinated with the technical aspects of Monolithic Dome construction. But besides those characteristics, the Monolithic Dome offers another that is vitally important today because it has to do with our environment. Monolithic Domes are green buildings – they are considered among the greenest of today’s building alternatives. Monolithic Domes conserve natural materials, space and electricity. Their construction does not deplete our planet’s shrinking forests.

Fig 4.5 Dome of a Home in Pensacola Beach in Florida

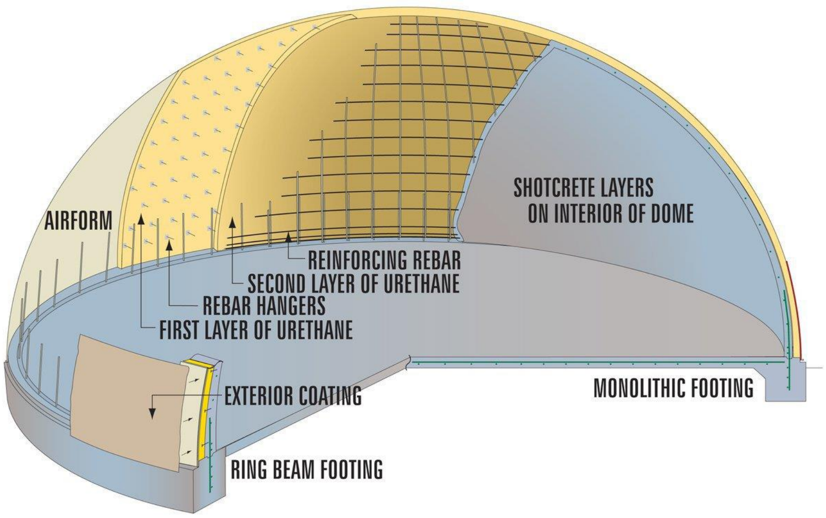
3. CHOOSING A PROFILE AND SHAPE

The profile of a dome determines the size of its surface area or dome shell, and the amount of surface area significantly affects construction cost. In other words, the more surface area there is, the more expensive it will be.

3.1 An Appropriate Profile

Sometimes people want a dome with a profile that is not appropriate to their needs. For example, a hemisphere dome is not a good choice for a church. A church has no practical use for all that space above the congregation.

On the other hand, that very same hemisphere is a most appropriate choice for a bulk storage facility. If you're storing fertilizer, for example, you want and need all that upper space. You might even consider designing your storage dome with an integrated stemwall of twenty, thirty or forty feet and topping it with a hemisphere. We have illustrated three domes, each with exactly the same amount of floor area below 14 feet in height. But each has a different footprint and a different surface area. It's important that dome buyers understand these relationships so they can get the maximum benefit for their money.



4. THE CONSTRUCTION PROCESS

Fig 6.1 Cutaway — Schematic cutaway of the layers of the final Monolithic Dome

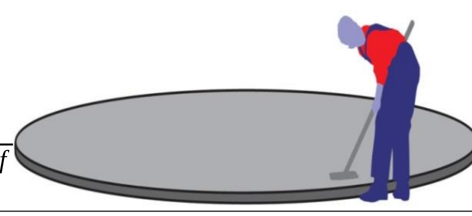
Monolithic Domes are constructed following a patented method that requires a tough, inflatable Airform, steel-reinforced concrete and polyurethane foam insulation. Each of these ingredients is used in a technologically specific way.

4.1 Footing

A Monolithic Dome starts as a concrete ring foundation, reinforced with steel rebar. For smaller domes, an integrated floor and ring foundation may be used. Vertical steel bars embedded in the ring beam footing are later attached to the steel reinforcing of the dome itself. In the foundation and slab a standard 5 sack (470 pound cement per cubic yard), (214 kg cement per 0.76 cubic meter) concrete foundation mix was used. Concrete used in the dome shell was a 9 sack per cubic yard (0.7647 cubic meter) mix.

4.2 Airform

Fabricated to a proper shape and size, is attached to the concrete base. Using fans,



Dept. of

the Airform is inflated - creating the shape of the dome and is both the form for construction of the dome and the outer roof membrane of the shell when it is finished. The inflator fans run throughout the construction of the dome shell. First rebar is bent over so that the Airform can be slid over the rebar and attached to the footing. Then airfoam is attached using thin metal strap that is screwed on the outside with concrete screw anchors. Then inflate the airfoam. The airform kit was obtained from Monolithic constructors, Italy, Texas. Keeping the air pressure in a dome is the most important factor during dome construction .

Fig 6.3 Prepare the ring beam for attaching Airform & Dome is inflated using dual fans

4.3 Foam

Approximately three inches of polyurethane foam insulation is applied to the interior surface of the Airform. Polyurethane foam provides a complete, seamless building envelope, creating a more comfortable indoor environment for the life of your home. Its purposes are to give rigidity to the air form, secure the rebar in place, provide support for spraying in the concrete mixture, and insulate the final structure. The Polyurethane foam seals cracks, crevices and seams around the perimeter of dome home. Give valuable protection from unmanaged air infiltration, drafts and damaging moisture accumulation in walls. Prove that more effective than conventional insulation products. Spray polyurethane insulation forms a seamless bond with building components to create a structurally sound, uniform, air-infiltration barrier. Polyurethane foam's unique physical properties perform in even the most extreme hot or cold climates. They do not need fasteners to hold it into place. They are light in weight.

4.4 Rebar

Steel reinforced bars, or rebar, is attached to the foam using special hooks embedded in the foam. The rebar is placed in a specially engineered layout of hoop (horizontal) and vertical steel rebar. Steel in the foundation and slab was 5/8 inch (16mm) and ½ inch (13mm) grade 40 rebar. In the dome shell, ½ inch (13mm) and 3/8 inch (9.5mm) grade 60 rebar was used.

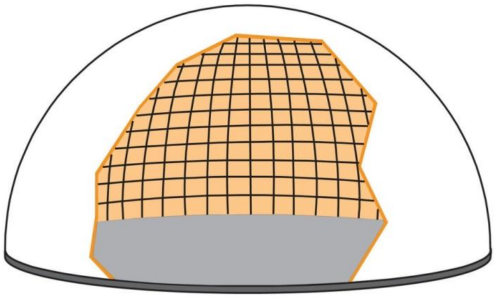


Fig 6.5 Rebar

4.5 Shotcrete

A special spray mix of concrete is sprayed onto the interior surface of the polyurethane form, embedding the rebar. After three inches of shotcrete is applied, the Monolithic Dome is a steel reinforced, concrete structure.

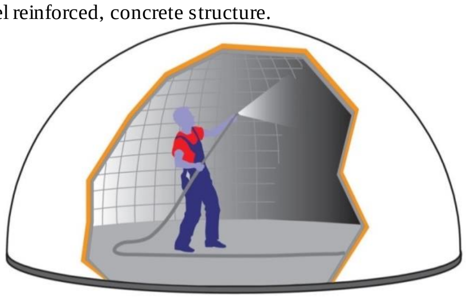


Fig 6.6 Shotcrete Application

4.6 Exterior

Exterior coatings are an essential aspect in the longevity to the Dome Exterior. Coatings serve as a UV shield to protect the Airform and foam insulation as well as achieve a desired appearance. PVC skin is available in colors for exterior coating, painting and repainting is not required, only and occasional washing off of dust.

5. SPECIAL FEATURES OF MONOLITHIC DOME

5.1 The Strength Of The Monolithic Dome

The monolithic domes have the strength to withstand tornadoes, hurricanes and earthquakes. The unbeatable strength comes from the concrete and steel used in the dome's construction and from its rounded shape. Monolithic Domes are the most disaster-resistant structures that can be built affordably.The FEMA manual (FEMA, 2000) is a guidance manual for engineers, architects, building officials and prospective shelter owners. It presents important information about the design and construction of community shelters that provide protection during tornado and hurricane events.

Conventional buildings have walls connected to foundations and to roofs with specially designed connectors, while a Monolithic Dome is continuously attached throughout with steel reinforcement greatly in excess of that required to resist extreme wind forces. When doors and windows are open on a conventional structure or when a rapid change in pressure creates large internal as well as external forces, the Monolithic Dome resists both of these conditions without special details of construction. For a Monolithic Concrete Dome that is pre-stressed in biaxial compression and double curved, representing the upper roof portion of a large dome and 3 to 4 inches thick with 3 inches of urethane foam insulation on the outside plus an outer covering of heavy nylon reinforced fabric , and reinforced with 3 rebar at 12 inches both ways, is also capable of resisting the 100 mph missile test. The testing that has been done to date represents flat walls with the missile hitting perpendicularly to the wall. The dome surface will resist greater forces in three ways. The double curved surface is much more resistant than a flat surface;

5.2 Antiterrorism buildings

Monolithic Domes can withstand terrorist attacks better than most conventional buildings. Thin shell concrete structures stand up to allied bombing . During World War II, thin shell concrete buildings faired much better than other structures and further reported that during bombing incidents, if thin shells took a direct hit, either the bombs ricocheted off the structures and exploded away from the buildings or they penetrated the shell and went off inside. In either case, the bombs did not bring the buildings down. If the explosive created a hole in the shell, patching the damage was not difficult and cleanup and remodeling could be safely done inside. Further checking with our thin shell engineer revealed that a three-inch-thick, concrete thin shell could withstand more of a bomb blast than a twelve-inch- thick, highly reinforced, concrete straight wall.

5.3 Biological Containment

Biological containment by a Monolithic Dome is inherent. Because they are air tight structures, Monolithic Domes offer major protection from gas, radiation and bio-hazards. This is especially important for schools, military command centers and other large capacity buildings.

5.4 Withstanding Small Arms And Direct Fire Weapons

Monolithic Domes can protect occupants from most indirect fire weapons, as well as small arms fire and many other direct fire weapons. We have tested this on our own buildings. This protection capability of the Monolithic Dome can be further enhanced by covering the Airform with concrete. The concrete-foam-concrete sandwich is the best protection against weapons fire.

5.5 Military Applications

A quick study of Monolithic Domes can show that they are the logical buildings for most military applications. Their cost of construction is reasonable. They require less materials to construct and are generally faster to build than conventional buildings. Energy reduction is usually 50% or more . They are permanent. And they are easy to lock down and defend hostile entities would find it very difficult to break through a Monolithic Dome. More importantly, Monolithic Domes can withstand natural and man-made disasters. They make excellent munition storages reducing the risk of detonating the contents by hostile fire.

5.6 Insurance Rates

Insurance rates for a Monolithic Dome are substantially less. Monolithic Domes are rated as non-combustible. Due to the Monolithic Dome's non-combustible rating and resistance to damage in other forms, risk to the insurance company is very small and premium savings of 75% or more are quite realistic.

5.7 Earthquake resistant

Earthquake forces do not even approach the design strength the Monolithic Dome is built to withstand under normal every day usage. It would take an external force much larger than an earthquake to approach the design strength of the concrete itself. Earthquake character of a monolithic dome can be studied by conducting Shake table test, which shows that the dome shape is virtually earthquake-proof. This seismic tests done at the University of British Columbia in the Department of Civil Engineering's Earthquake Engineering Research Facility, even if the same materials are used to build the dome as are used in construction of conventionally shaped buildings such as wood the dome shape, itself, is enough to afford drastically increased protection from seismic activity.

6. TYPICAL PLAN OF MONOLITHIC DOME HOME

The future is shown with the concept monolithic dome home which is shown in (Figures 8.1-8.3). This 50' diameter concrete monolithic home would provide for safe environment. A basement and a garage on the lower level for two cars are considered. The main entry of the house can be accessed on the first level from covered concrete stairs. Inside includes 3 bedrooms and 2 baths with each of the bedrooms large enough to accommodate an extra bed. Dormers over each of the windows will provide shade. The concept home will have an area of approximately 1800 square feet on main level and same on lower levelmaking it safe. On the main level, the closet in the master bedroom is the safest area on this level. The low profile spherical shape of dome home can protect its occupants from storms and tornado wind. Tornado proof windows, entry and garage doors can be installed. It is an added cost, but costs go down with mass production.

7.CONCLUSION

Monolithic is dedicated to improving people's lives worldwide by introducing and constructing Monolithic Domes, for personal and public use, that are disaster-resistant, energy-efficient and cost-effective. Monolithic Domes are the most energy efficient and safest buildings that can be built and that can be designed for many uses. Many schools now conduct their classes in Monolithic Domes. Some are designated as tornado shelters. Others have Monolithic Dome gymnasiums, auditoriums, multipurpose centers, libraries, cafeterias, etc. Because Monolithic technology meets criteria for a structure that can provide near-absolute disaster protection, And in most cases, they save money on first cost for the construction. The monolithic dome has sufficient durability and which offers exceptional resistance to earthquake, fire and extreme wind.

RESERVOIR SURVEY USING IBS AND SUB-BOTTOM PROFILER

Ms. HARSHA UNNI K.

S8 – Civil Engineering

Sreepathy Institute of Management and Technology,

Vavanoor, India

Ms. ASWATHI M.P.

S8 – Civil Engineering

Sreepathy Institute of Management and Technology,

Vavanoor, India

ABSTRACT

Hydrographic survey is the branch of surveying which deals with anybody of still or running water such as lake, stream or river. It used to determine the bed depth by soundings, for navigation, location of rocks and sand bars, for under water works, irrigation and land drainage schemes. In a hydrographic survey, the actual measurement of the water depth is the easy part. This information used for planning, management and operation activity of the reservoirs. Traditionally reservoir sedimentation has been studied by carrying out bottom topographic survey using boat, sextant, ranging rods, echo-sounder etc. Naturally, this involved lot of time and the outcome was susceptible to human error because of monotony of work. Also it is laborious, and costly method. Integrated bathymetric system and (IBS) sub-bottom profiler has been found to be an ideal solution to all the above rigorous work. This method comprising human, hardware and software. This paper mainly gives an over view of IBS and Sub-bottom profiler.

1. INTRODUCTION

Release of bed load and deposition of suspended materials carried by inflow in the reservoir comprise the sedimentation process. The sediment deposition has adverse effect such as reduction in storage capacity, increase in back water level, formation of shoals. For effective planning and use of stored water optimally it is necessary to find the actual rate of sedimentation and revised capacity of reservoirs. Therefore hydrographic survey (sedimentation survey) is to be carried out periodically for every reservoir. The conventional techniques and integrated technique are mainly used to determine the storage capacity of reservoirs. In conventional method conventional equipment like Theodolite, Level, Sextant, Range finder, Sounding rods, Echo-sounders, Current meter, Motor boat etc. are employed. Predetermined cross sections are marked by constructing range monuments on either side of the bank. Hydrographic survey is carried out along these range lines. The recent development in field of sedimentation survey comprises use of integrated bathymetric system (IBS) consisting of Digital Echo-Sounder, DGPS for accurate positioning, Computer & Software for collecting data and analysis of data. Using computer software, the sedimentation survey becomes easy, accurate and time saving. It also provides pictorial presentation of contour map and bottom morphology of the reservoir. Sub-bottom profiling is another system employed to identify and characterize layers of sediment or rock under the reservoir. These systems also can be helpful in locating hard objects buried beneath the bed level. So this combination of IBS & Sub-bottom profiling give the accurate and better result in reservoir survey.

2. INTEGRATED BATHYMETRIC SYSTEM

2.1 The System

The system consists of modern sophisticated electronic equipments. Data collection, processing and calculations are done by means of computer software. The results are more accurate than the Conventional survey methods.

2.2 Equipments Used

2.2.1 Differential Global positioning system (DGPS)

Leica MX 9250 (Reference Station) with UHF transmitter link along with choke-ring Antenna forms stationary part of DGPS. It can track up to 12 satellites to achieve accurate position. The corrections are displayed in the display. It transmits the data to the mobile station.

2.2.2 DGPS Leica MX 420(mobile station)

DGPS Navigator is one such highly reliable, accurate, state of art device to get position by observing satellite. It can also track up to 12 satellites to achieve maximum positional accuracy. The DGPS receiver receives error correction from reference station and combines them with the received satellite signals to compute much more accurate self position. The validity of error correction decreases with the distance from the reference stations, however they are valid up to 80 Km. The accuracy in position is less than 1m.This DGPS system is provided in the survey boat or vessel.

2.2.3 NS-415 Echo-sounder

Navitronic Echo-sounder NS 415 is designed to measure under water depth up to 1200m. Accuracy of instrument is 1centi meter. A dual frequency echo-sounder is specified to distinguish between fluff top depth and the consolidated bottom. The high frequency (200 KHz) is used to detect the top of the mud/sediment. Under favorable conditions the low frequency signal (33 KHz) can penetrate into the bottom and reveal information about the bottom structure.

2.2.4 Sound Velocity Probe

The velocity of sound under water depends on many parameters such as depth, temperature, salinity etc. A sound velocity calibrator is necessary to calculate the velocity of sound for taking the accurate depth readings by Navi Sound echo-sounder.

2.2.5 Survey PC (Laptop)

The Navisoft survey software installed in the PC (laptop) controls the Bathymetric data collection. All the data collected using DGPS and echo-sounder are recorded in computer and processed.

2.3 Software

Mainly two type of software are used in this method of survey. One of them is used for data collection and processing and other is a graphic program used for calculating the volume based on the logged data. Bathy 2010 software or Navisoft can be used for data collection and processing software. Hypack or surfer software are used as the graphic program software. Echo-sounder was operated through Bathy 2010 Software or Navisoft. All position and sounding data were stored in this software. From Bathy 2010 Software, data were exported to Hypack. Hypack then stored all the data and guided in maintaining the survey vessel position. End products for a reservoir mainly include accurate stage-areas and stage-storage relationships, generation of 3D reservoir surface, creation of contour map of the reservoir elevations, etc.

3. STEPS INVOLVED IN HYDROGRAPHIC SURVEYING

3.1 Pre-Survey Planning

In order to conduct an accurate and efficient survey, there are some pre-survey planning steps, which need to be taken before the actual survey. The pre-survey planning mainly includes acquisition of the background image of the study area, which may be obtained from Google Earth, through remote sensing or aerial photography, and then importing the image to Software for geo-referencing. After geo-referencing, the image is used for drawing the survey paths.

3.2 Performing Hydrographic Survey

In hydrographic surveying with this approach, generally a crew of three members is involved, one is the boatman to operate and maintain the survey vessel's position on planned survey paths. Second member is to operate the equipment and the third member may be required for equipment mounting and/or as boat helper. The transducer is mounted on one side of the boat, with DGPS antenna directly above it. Survey is performed on the planned survey paths, as decided in the in-house planning. The echo-sounder and DGPS start data acquisition simultaneously, using the software. The survey vessel is maneuvered on the pre-defined survey path.

3.2.1 Installation of reference station

The first step in DGPS based survey is to select the location of reference station, for getting accurate position. The reference station is one which is fixed on the land from which the corrected positions are transmitted to mobile station for survey and it should cover maximum area. The reference station was fixed at ground. Reference station was configured in self survey mode for 24 hours. This mode determines antenna position with an accuracy of one meter.

3.2.2 Launching of boat

The survey boat was launched and retrieved in the reservoir with the help of boat trailer,in to reservoir. The survey boat should be travelled through the predetermined path prepared in the pre-survey planning process.

3.2.3 Installation of NS 415 echo-sounder and GPS mobile station

In this stage installation mobile station in boat or survey vessel is set up as shown in figure 3.1. NS 415 echo-sounder, DGPS navigator, source of electric supply, laptop and receiving antenna are the main equipments installed in the survey boat.

3.3 Post Processing

Post processing is the most important part of hydrographic surveying. It is mainly performed in order to improve the quality of collected data by removing errors and filling gaps for missing data. After improving the quality, the data are used to produce the end products. Raw bathymetric data are processed and analyzed in Software in order to filter multiple return acoustic signals, soundings with random errors and noise, GPS error and remaining gap near shore for inaccessible areas with the boat. The Raw data are viewed, corrected and saved in edit files. In order to determine the reservoir area and reservoir volume from survey data, a variety of options is available in the Software including Triangular Irregular Network (TIN). TINs are used to store and display surface models (ESRI). A digitized polygon enclosing the collected data can be developed such that interpolation is not allowed to come outside the boundary.

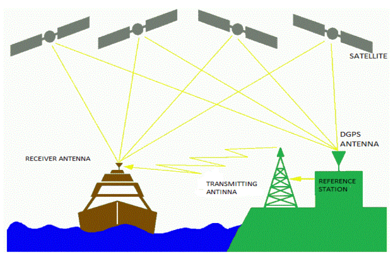


Fig 1 The DGPS positioning

4. SUB-BOTTOM PROFILER

Fig 2 The sub-bottom profilers

A sub-bottom profiling system was used to obtain information of the sediments beneath the surface of the reservoir bottom. Also known as single channel seismic systems, these send out a focused acoustic signal to the reservoir bottom. Some of the energy is reflected by the bottom, but a portion of the energy penetrates into the sediments and rock. The time it takes for the reflected sound pulses to return to the surface vessel can be used to determine the thickness of the sub-bottom layers in the bottom of reservoir and how the layers are positioned (e.g., level or sloped). The reflected sound also gives some limited information about the composition of the various layers. Refracted sound pulses, which follow a more complex path, provide additional information about the sub-bottom layers. Through analysis of the seismic refraction, a more comprehensive understanding of the density of various sub-bottom layers can be developed. The variability in density shows the relative differences of the sediment, with greater density showing harder materials.

Each time the signal encounters a different material, a portion of the energy is reflected, and the system records these reflected signals. Combining these reflections produces an image of the sub-bottom structure of the reservoir bed. The resolution and penetration of these systems depend on their frequency. Generally, sound will penetrate to greater depths with lower frequencies but better resolution can be achieved with higher frequencies. High water content silts can be acoustically transparent at a frequency of 3.5 kHz but 3.5 kHz may be needed to reach bedrock through sand layers. A 200 kHz frequency transmission may be needed to detect the more transparent layers typical near the surface of the bottom. Additional frequencies may be needed to define fine layering between the rock and the sediment surface. While some sediments can be penetrated nearly 100 meters at 12 kHz, other sediments may not allow even 3.5 kHz sound to penetrate more than a few meters. Still other sediments may be so acoustically transparent that 12 kHz may miss the interface between the water and the surface of the bottom and thus report erroneously deep depth. The software used in this method is the online software "SES for Windows" (SESWIN), provides a user friendly system configuration and system control during the survey. Optimized signal processing algorithms give very good online results on the screen and on the printer too.

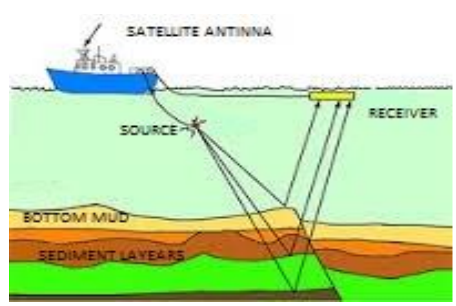


Fig 3 Sub-bottom profiling

5. COMPARISON OF TRADITIONAL AND INTEGRATED METHOD

Table 1

Sr. No.	Item	Traditional Method	Integrated Approach
1	Main equipment	Different equipments for different purposes.	Integrated equipments are used.
2	Software	-	Software used
3	Survey crew	About 15 persons	3 persons
4	Time	Six weeks required covering whole reservoir	One week
5	Post processing	Eight weeks	One week
6	Preparation of end products	Twelve weeks	One week
7	Product's type	Contour map, stage-storage relationship, reservoir capacity	Under water terrain, storage capacity, stage storage relationship, 3D reservoir surface

6. LIMITATIONS OF INTEGRATED METHOD

- The reservoir survey using IBS and sub-bottom profiler is different from conventional method, because of the use of modern equipments and software. So it needed specially trained crews for conducting this survey.
- This system requires costly equipments.
- Survey can only conduct in fully reservoir condition.

7. CONCLUSION

The methodology of bathymetric surveys with sub-bottom profiler is well developed and is generally seen as the best available method to assess basin sediment export, though with the limitation that it can of course only be applied when a reservoir is present. In this paper an integrated approach of hydrographic surveying was introduced, elaborated and compared with the traditional approaches. It has been found that the new integrated approach is more efficient in terms of saving resources (humans and time), improving accuracy, ease of operation of the equipment, automatic analytical facilities and a large variety of end products. End products for a reservoir mainly include accurate stage-areas and stage-storage relationships, generation of 3D reservoir surface, creation of contour map of the reservoir elevations, etc. In comparison with conventional approaches the integrated approach with sub-bottom profiling reduces the survey crew to about three persons instead of 15 in conventional approaches. Survey can be performed in much less time as compared to traditional approaches, as in case of Tarbela Reservoir it can be performed in one week, instead of four weeks in old approach. Similarly, data analysis and interpretation can be performed in one week with a large variety of end products, instead of two to three months in traditional approaches, with limited variety of end products.

REFERENCES

1. Sarfraz Munir, et al (2014): "An Integrated Approach to Hydrographic Surveying of Large Reservoirs—Application to Tarbela Reservoir in Pakistan", *Open Journal Of Modern Hydrology*, Vol.4,pp.156-163.
2. OleGrøn and LarsOleBoldreel (2014): "Chirping for Large-Scale Maritime Archaeological Survey: A Strategy Developed from a Practical Experience-Based Approach", *Journal of Archaeology*, Vol.2014, january 2014 .
3. Joris de Vente, et al (2006): "Evaluation of reservoir sedimentation as a methodology for sediment yield assessment in the Mediterranean: challenges and limitations", *scape* .
4. Ben K. Odhiambo and Stephen K. Boss (2006): "Watershed Physiography, Land Use, and Sediment Yield: A Case Study from Northwest Arkansas, USA", Journal of Spatial Hydrology ,Vol.6, No.1.

TREATMENT OPTIONS AND REUSE OF DISTILLERY WASTEWATER

Sreerag K. P.
8th Semester,
Register no: SYALECE044,
Department of Civil Engineering,
Sreepathy Institute of Management and Technology (SIMAT), Vavanoor, Palakkad

Abstract:- One of the most important environmental problems faced by the world is management of wastes. Industrial processes create a variety of wastewater pollutants which are difficult and costly to treat. Wastewater characteristics and levels of pollutants vary significantly from industry to industry. Now-a-days emphasis is laid on waste minimization and revenue generation through byproduct recovery. Pollution prevention focuses on preventing the generation of wastes, while waste minimization refers to reducing the volume or toxicity of hazardous wastes by water recycling and reuse, and process modifications and the byproduct recovery as a fall out of manufacturing process creates ample scope for revenue generation thereby offsetting the costs substantially. Production of ethyl alcohol in distilleries based on cane sugar molasses constitutes a major industry in Asia and South America. The world's total production of alcohol from cane molasses is more than13 million m^3/annum. The aqueous distillery effluent stream known as spent wash is a dark brown highly organic effluent and is approximately 12-15 times by volume of the product alcohol. It is one of the most complex, troublesome and strongest organic industrial effluents, having extremely high COD and BOD values. Because of the high concentration of organic load, distillery spent wash is a potential source of renewable energy. The paper reviews the status and appropriate treatment alternatives for disposal of the distillery wastewater .

1. INTRODUCTION

Alcohol production through the process of fermentation is an industrial activity implemented almost world-wide. Due to the agricultural origin of the primary matter used, distilleries are usually located in rural areas. Agricultural products like sugar cane, sugar beet, different cereals, grapes etc. are either fermented directly or in the form of sub-products, after being processed in order to condition the sugar contained in the plants for the alcoholic depending on the required concentration of ethanol – produces a highly polluting residue. For the production of every litre of alcohol, 10 to 30 litres of industrial wastewater, called vinasse, stillage or slops, are generated. Its organic load is high, varying from 20 to 120 g COD (or 2,000-12,000 mg) per litre, the effluent temperature is high (around 90 ^{o}C), the average pH-value is low (3.5 to 6). Table:1 represents a summary of research results on cane molasses, confirming these average values. The named characteristics make the distillery wastewater one of the industrial residues most difficult to treat and dispose off properly .

TABLE 1.1
AVERAGE VALUES FOR STILLAGE FROM CANE MOLASSES

Parameter	**Range of Values for Cane Molasses**
pH	3.5 – 5.7
Temperature	80 – 105 °C
COD	15 – 176 g/l

Distilleries are very large agro-based chemical industry in India where ethyl alcohol is produced by fermentation of cane sugar molasses. The fermentation broth containing 6-8% alcohol by volume is distilled to recover alcohol. The distilleries generate 12-17m^3 of wastewater per m^3 of alcohol produced. A distillery industry discharges approximately 100-1000 m^3/day wastewater depending on the size of the process. Alcohol is separated by distillation and the residual liquor is discharged as effluent. This effluent is called as 'spent wash', which is characterized by highly acidic, high BOD and COD, high recalcitrant organics with dark in color. Of the various treatment methods for distillery wastewater, anaerobic digestion has gained wide acceptability due to methane recovery in the anaerobic step of the treatment. It is reported that anaerobic treatment results in 60-85% of the BOD reduction, but still substantial amount of recalcitrant organic pollutants are left behind which requires post treatment. Considerable research work has been carried out in the past to evaluate alternate options for abating the pollution potential of predigested distillery effluent. They include physicochemical method and biological methods such as bioremediation. Electrochemical treatment has attracted great attention in treating industrial wastewater because of the versatility and its environmental compatibility. Electrochemical treatment is widely used to treat different industrial effluxents with varying degree of treatment and with different experimental conditions .

Rapid growth of distilleries in India resulted into substantial increase in industrial pollutant load. There are 254 distilleries in India producing 1000 million liters of alcohol and 3.5x 108 kiloliters of effluent each year. The industrial wastes generated by various distillery units are posing serious threat to the adjoining aquatic and terrestrial habitats due to practice of discharging them into nearby waste water courses and lands. The distillery effluents have high BOD, COD, phenols & heavy metals. The colour of the effluent persists even after the anaerobic treatment and poses a serious threat to environment. The water bodies receiving colour wastes got colored and affect the penetration of light in aquatic ecosystems, which in turn affect the aquatic life. Therefore, it is essential to reduce the toxic level of various pollutants in the distillery effluent before discharging them into nearby watercourses or lands .

2. OPERATIONS INVOLVED IN A DISTILLATION PROCESS

2.1 Distillery Process

The production of distilled spirits is based upon fermentation, the natural process of decomposition of organic materials containing carbohydrates. It occurs in nature whenever the two necessary ingredients, carbohydrate and yeast, are available. Yeast is a vegetative microorganism that lives and multiplies in media containing carbohydrates - particularly simple sugars. It has been found throughout the world, including frozen areas and deserts. Distilled spirits are all alcoholic beverages in which the concentration of ethyl alcohol has been increased above that of the original fermented mixture by a method called distillation. The principle of alcoholic distillation is based upon the different boiling points of alcohol (78.5 °C, or 173.3 °F) and water (100 °C, or 212 °F). If a liquid containing ethyl alcohol is heated to a temperature above 78.5 °C but below 100 °C and the vapour coming off the liquid is condensed, the condensate will have a higher alcohol concentration, or strength .

Many people mistake the distilling process as the “alcohol creation” process. Rather is it the process in which a chemical, in this case ethanol alcohol, is removed from another chemical. The process is centuries old, and is used in a myriad of applications from alcohol distillation to essential oil extraction. However alcohol manufacture in distilleries consists of four main steps viz. Feed preparation, Fermentation, Distillation and Packaging .

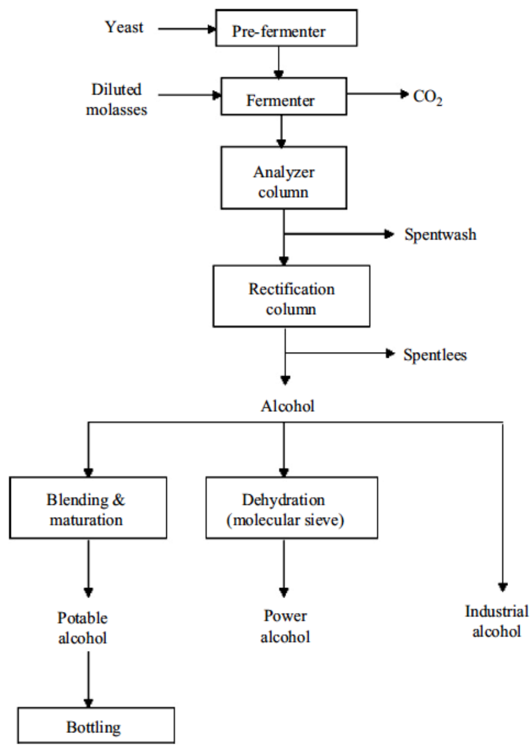


Fig.No: 2.1 Distillery Process

2.1.1 Feed preparation

Ethanol can be produced from a wide range of feedstock. These include sugar-based (cane and beet molasses, cane juice), starch-based (corn, wheat, cassava, rice, barley) and cellulosic (crop residues, sugarcane bagasse, wood, municipal solid wastes) materials. In general, sugar-based feedstock containing readily available fermentable sugars are preferred since starch and cellulosic substrates involve an additional pre-treatment step to convert starch into fermentable sugars. Thus, cane juice is a commonly used substrate in Brazil while Indian distilleries almost exclusively use sugarcane molasses. Overall, nearly 61% of world ethanol production is from sugar crops. The composition of molasses varies with the variety of cane, the agro climatic conditions of the region, sugar manufacturing process and handling and storage. Molasses is diluted to about 20–25 brix (measurement of sugar concentration in a solution) and its pH adjusted, if required, before fermentation. In India, about 90% of the molasses produced in cane sugar manufacture is consumed in ethanol production .

2.1.2 Fermentation

Yeast culture is prepared in the laboratory and propagated in a series of fermenters, each about 10 times larger than the previous one. The feed is inoculated with about 10% by volume of yeast (Saccharomyces cerevisiae) inoculum. This is an anaerobic process carried out under controlled conditions of temperature and pH wherein reducing sugars are broken down to ethyl alcohol and carbon dioxide. The reaction is exothermic. To maintain the temperature between 25 and 32 ^{o}C plate heat exchangers are used; alternatively some units spray cooling water on the fermenter walls. Fermentation can be carried out in either batch or continuous mode. Fermentation time for batch operation is typically 24–36 hours with an efficiency of about 95%. Continuous operation, involving higher sugar concentration and an osmotolerant variety of yeast is faster (16–24 hour fermentation time) but the efficiency is marginally lower. The resulting broth contains 6-8% alcohol. The sludge (mainly yeast cells) is separated by settling and discharged from the bottom, while the cell free fermentation broth is sent for distillation.

2.1.3 Distillation

Distillation is a two-stage process and is typically carried out in a series of bubble cap fractionating columns. The first stage consists of the analyzer column and is followed by rectification columns. The cell free fermentation broth (wash) is preheated to about 90 °C by heat exchange with the effluent (spentwash) and then sent to the degasifying section of the analyzer column. Here, the liquor is heated by live steam and fractionated to give about 40–45% alcohol. The bottom discharge from the analyzer column is the spentwash. The alcohol vapors are led to the rectification column where by reflux action, 96% alcohol is tapped, cooled and collected. The condensed water from this stage, known as 'spentlees' is usually pumped back to the analyzer column .

2.1.4 Maturation, blending, and packaging

Rectified spirit (96% ethanol by volume) is marketed directly for the manufacture of chemicals such as acetic acid, acetone, oxalic acid and absolute alcohol. Denatured ethanol for industrial and laboratory use typically contains 60–95% ethanol as well as between 1% to 5% each of methanol, isopropanol, methyl isobutyl ketone, ethyl acetate, etc. For beverages, the alcohol is matured and blended with malt alcohol (for manufacture of whisky) and diluted to requisite strength to obtain the desired type of liquor. This is bottled appropriately in a bottling plant. Anhydrous ethanol for fuel-blending applications (power alcohol) requires concentration of the ethanol to >99.5 wt% purity. The ethanol dehydration is typically done using molecular sieves; however, pervaporation has also been employed in Brazil and India for this purpose .

2.1.4.1 Maturation

One method of classifying distilled liquors is as aged or unaged. Vodka, neutral spirits for use in a variety of products, most gins, and some rums and brandies are unaged. Aged products are predominantly whiskeys and most rums and brandies.

The term age refers to the actual duration of storage, while maturity expresses the degree to which chemical changes occur during storage. Mostly white-oak containers are used for the maturation of alcohols. White oak is one of the few woods that can hold liquids while allowing the process of breathing through the pores of the wood. The pore size of the wood is such that small molecules such as water move through the wood more easily than larger molecules such as alcohol. This breathing process is caused by temperature and humidity differences between the liquid in the barrel and the air in the warehouse. Charring the wood makes some of the wood compounds more soluble. As the liquid in the container moves back and forth through the wood, ingredients are extracted and carried back into the container's contents. Maturation also results from the contact of oxygen from the outside air with ingredients in the alcohol mixture. Therefore, maturation during aging consists of the interaction of the original compounds of the distillate, of oxidation reactions, and of the extraction of flavouring compounds from the wood. These factors must be well balanced in the properly matured product .

2.1.4.2 Blending

Blending is another method of obtaining a balanced product with precise flavour characteristics. Blended products are composed of one or more highly flavoured components, a high-proof component with a low congener content, a colour adjustment ingredient, and perhaps an additional flavouring material. An example is a blended whiskey, which may contain several whiskeys, a grain spirit distilled at 90 to 95 percent alcohol, caramel colouring, and perhaps a small amount of a flavouring blender (part of which may be sherry or port wine). A blended Scotch consists of several highly flavoured malt whiskeys produced in pot stills and a base whiskey produced from grain in a continuous distillation system .

2.1.4.3 Packaging

Distilled spirits react upon exposure to many substances, extracting materials from the container that tend to destroy the liquor aroma and flavour. For this reason, glass, being nonreactive, has been the universal container for packaging alcoholic liquors. (A few products are now packaged in plastic bottles, but these are primarily 50-millilitre miniatures, the light weight of which is particularly suited for use by airlines.) Packaging economics require containers that are standardized in size and shape and that lend themselves to automatic processes.

Early hand methods of filling, labeling, corking, and other operations have been replaced by highly mechanized bottling lines, with bottles cleaned, filled, capped, sealed, labeled, and placed in a shipping container at a rate as high as 400 bottles per minute. This progress became possible with the development of high-strength glass, plastic closures with inert liners, and high-speed machines. Even specialized packaging, long a hand operation, has been replaced by standardization of containers, allowing production on automatic lines .

3. CHARACTERISTICS OF DISTILLERY WASTEWATER

3.1 Effluent Generation

The wastewater (effluent) generated in a distillery is of two types viz. Process Wastewater and Non-process Wastewater. The non-process wastewater is comparatively pure and as such can be recycled. The process wastewaters of a distillery consist of fermenter sludge, spent lees and spent wash. Spent lees is usually recycled. Fermenter Sludge has a higher Biochemical Oxygen Demand (BOD) and a lower volume as compared to spent wash. It is advisable to dewater fermenter sludge and dispose it off without mixing it with spent wash as it will increase the BOD of the receiving stream. The amount of effluent (wastewater) generated in a distillery depends upon the extent of process water used and the technology adopted for the manufacture of alcohol. Most of the Indian distilleries are of the conventional batch type in which about 15 KL of spent wash is produced per KL of alcohol .

3.2 Distillery Wastewater

Among the raw material sources for distillery, two very important raw materials are cane sugar molasses and beet sugar molasses. Distillery wastewater (stillage) is the main byproduct originating in distilleries, and its volume is approximately 10 times that of ethanol produced. It is not surprising that the utilization of the stillage raises serious problems, and that many attempts have been made all over the world to solve them. Distillery wastewater is usually comprised of a high volume of greatly acidic matter which presents many disposal and treatment problems. Waste streams generally contain high levels of both dissolved organic and inorganic materials. There has been increasing interest in the use of ethanol from biomass as a liquid fuel alternative. Ethanol fermentation is examined in relation to distillery wastes. In the year 1999, there were 285 distilleries in India producing 2.7 × 109 L of alcohol and 319 distilleries, producing 3.25×109 L of alcohol generating 4 × 1010 L of wastewater each year. Generating a 40.4 × 1010 L of wastewater annually. Reducing the volume of wastewater may be accomplished by fermenting higher strengths of molasses. To characterize distillery wastewater in detail so that proper insight may be gained in an attempt to treat the waste to reduce the pollution hazards. Oxygen consumption values can use to quantify the amount of organic matter present in wastewater. However, considerable work has been reported in this field and should be taken into account with the characteristics of distillery wastewater. Some of the work done on distillery waste characterization by various parameters like:- pH, COD, BOD, phosphate, total solids, total dissolved solids, total suspended solid, ammonia, sulfate, color and iron etc as in the Table 3.1

TABLE 3.1
TYPICAL CHARACTERISTICS OF DISTILLERY SPENTWASH

Parameter	**Range**
pH	3.8 – 4.4
Total solids (mg/L)	60000 - 90000
Total suspended solids (mg/L)	2000 - 14000
Total dissolved solids (mg/L)	58000 - 76000
Total volatile solids (mg/L)	45000 - 65000
COD (mg/L)	70000 - 98000
BOD (for 5 days at 20°C, mg/L)	45000 - 60000
Total nitrogen as N (mg/L)	1000 - 1200
Potash as K2O (mg/L)	5000 - 12000
Phosphate as PO4 (mg/L)	500 - 1500
Acidity as CaCO3 (mg/L)	8000 - 16000
Temperature (after heat exchange, °C)	70 - 80

The main source of wastewater generation is the distillation step wherein large volumes of dark brown effluent (termed as spentwash, stillage, slop or vinasse) is generated in the temperature range of 71–81 °C. The characteristics of the spentwash depend on the raw material used also, it is estimated that 88% of the molasses constituents end up as waste. Molasses spentwash has very high levels of BOD, COD, COD/BOD ratio as well as high potassium, phosphorus and sulphate content. In addition, cane molasses spentwash contains low molecular weight compounds such as lactic acid, glycerol, ethanol and acetic acid . Cane molasses also contains around 2% of a dark brown pigment called melanoidins that impart color to the spentwash. Melanoidins are low and high molecular weight polymers formed as one of the final products of Maillard reaction, which is a nonenzymatic browning reaction resulting from the reaction of reducing sugars and amino compounds. This reaction proceeds effectively at temperatures above 50 ^{o}C and pH 4–7. The structure of melanoidins is still not well known. Only 6–7% degradation of the melanoidins is achieved in the conventional anaerobic–aerobic effluent treatment process. Due to their antioxidant properties, melanoidins are toxic to many microorganisms involved in wastewater treatment. Apart from melanoidins, spentwash contains other colorants such as phenolics, caramel and melanin. Phenolics are more pronounced in cane molasses wastewater whereas melanin is significant in beet molasses.

4. TREATMENT METHODS OF DISTILLERY WASTEWATER

During the 1970s, land disposal was practiced one of the main treatment options, since it was found to enhance yield of certain crops. In Brazil waste generated from sugarcane juice fermentation is mainly used as a fertilizer due to its high nitrogen, phosphorus and organic content. It is use to increase sugarcane productivity and also under controlled conditions the effluent is capable of replacing application of inorganic fertilizers. However, for the high strength molassesbased spentwash, the odor, putrefaction and unpleasant landscape due to unsystematic disposal are concerns in land application. In addition, this option is subject to land availability in the vicinity of the distillery, also it is essential that the disposal site be located in a low–medium rainfall area. More recent investigations have indicated that land disposal of distillery effluent can lead to groundwater contamination. Deep well disposal is another option but limited underground storage and specific geological location limits this alternative. Other disposal methods like evaporation of spentwash to produce animal feed and incineration of spent wash for potash recovery have also been practiced .

A new strategy is required involving novel materials, methods and process integration options/technology for waste water treatment. There are several different methods for treatment of distillery effluent. They are as follows:

4.1 Biological Treatment Methods
- Anaerobic Treatment
- Aerobic Treatment

4.2. Physico-Chemical Treatment Methods
- Adsorption
- Coagulation and Flocculation
- Oxidation Process
- Membrane Treatment

- Evaporation / Combustion

4.1. Biological Treatment Methods

4.1.1 Anaerobic Treatment

Application of anaerobic digestion to distillery effluents is a preferable primary treatment option. Since aerobic processes have higher nutrient requirements and cause operational difficulties in treating high organic strength wastewaters, employing these methods in primary treatment of stillage would result in lower cost-efficiency. Most of the anaerobic technologies applied so far in the treatment of high organic strength wastewaters- municipal and originated from other industry branches-were employed for effluents from ethanol manufacture, achieving high levels of pollutants decay. The anaerobic treatment of brewery waste water in UASB system could be good method of organic, easily biodegradable wastewater utilization. The achieved efficiency of COD removal was satisfactory, it reached over 95%.During the experiment the properties of anaerobic granular sludge was also controlled.

The high organic content of molasses spentwash makes anaerobic treatment attractive in comparison to direct aerobic treatment. Therefore, biomethanation is the primary treatment step and is often followed by two-stage aerobic treatment before discharge into a water body or on land for irrigation. Aerobic treatment alone is not feasible due to the high energy consumption for aeration, cooling, etc. Moreover, 50% of the COD is converted to sludge after aerobic treatment. In contrast, anaerobic treatment converts over half of the effluent COD into biogas. Anaerobic treatment can be successfully operated at high organic loading rates; also, the biogas thus generated can be utilized for steam generation in the boilers thereby meeting the energy demands of the unit. Further, low nutrient requirements and stabilized sludge production are other associated benefits. The performance and treatment efficiency of anaerobic process can be influenced both by inoculum source and feed pre-treatment. In particular, thermal treatment of wastewaters can result in rapid degradation of organic matter leading to lower hydraulic residence time (HRT), higher loading rate and BOD reduction. Two various anaerobic applications covering both laboratory studies and commercial scale operations for treatment of molasses-based distillery wastewaters are,

4.1.1.1 Two Step Anaerobic Filter :

The wastewater is first sieved and then goes to the storage. The tank used can store the total volume produced. The wastewater goes to 5m^3 acidogenic reactor with temperature and pH control (37 ^{o}C and 6.5 respectively). The acidogenic wastewater reaches 4 m^3 anaerobic filter and goes to the 15 m^3 aerobic post treatment. The biogas is burnt by a flare. This strategy, with the full storage of the wastewater, allows a small volume of reactor and treatment during all the year. In the acidogenic phase, the soluble COD removal yield is 24% and the hydraulic residence time (HRT) was 20 to 38 hours. The organic loads of the anaerobic filter are between 4.6 to 11 kg of COD/m^3/d with an average yield of 70%. The organic load of the aerobic post-treatment is 1.3 kg COD/m^3/d. The COD removal yield of the overall process was between 88 to 98% .

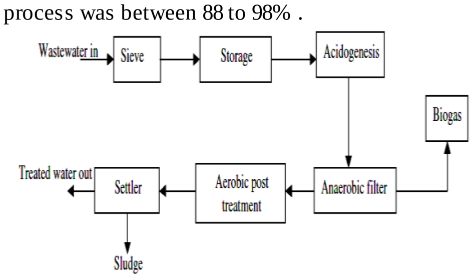


Fig. no: 4.1 Flow-chart of the Two-Step Anaerobic Treatment

4.1.1.2 The Upflow Anaerobic Sludge Blanket (UASB) application technology :

The wastewater is sieved and goes into the settler before storing in an tank. In this tank the acidification occur as well as in the additional storage tank. Two UASB digesters remove the principal part of the pollution. The wastewaters goes in after the aerobic post-treatment composed with 2 basins and two settlers. Nutrient, phosphorus and nitrogen are added to reach a good balance for aerobic growth. Part of the treated wastewater can be used for dilution, if required. The aerobic sludge is de-watered by reed sludge bed process .

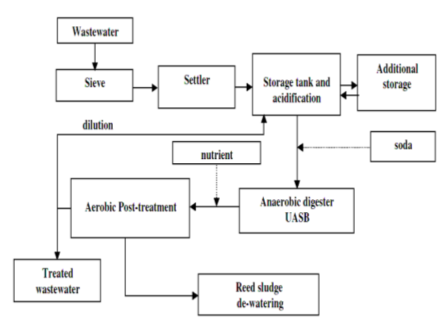


Fig. No: 4.2 Flow chart of UASB Application Technology

4.1.2 Aerobic Treatment

The post-anaerobic treatment stage effluent still has high organic loading and is dark brown in color, hence it is generally followed by a secondary, aerobic treatment. Solar drying of biomethanated spentwash is one option but the large land area requirement limits this practice. Further, in India, solar drying beds become non-functional during the rainy season. Some aerobic treatment methods :

4.1.2.1 Aquaculture : Post-biomethanted effluent has been used for pisciculture near Chennai city in southern India. The biodigested effluent, which is a rich growth medium, is directed to bioconversion ponds after which it is spread in about 6 ha of fishponds. The BOD is reduced to nearly zero and the initiative yields about 50 tons per hectare per year of fish .

4.1.2.2 Constructed Wetlands : The post-anaerobic treated effluent had a BOD of about 2500 mg/l and a COD of nearly 14,000 mg/l. A pre-treatment chamber filled with gravel was used to capture the suspended solids. All the cells were filled with gravel up to varying heights. The overall retention time was 14.4 days and the treatment resulted in 64% COD, 85% BOD, 42% total solids and 79% phosphorus content reduction .

4.1.2.3 Biocomposting : Biocomposting is an aerobic, thermophilic process resulting in a product rich in humus which is thus used as a fertilizer. This is a popular option adopted by several Indian distilleries attached to sugar mills with adequate land availability. The spent wash, either directly, or after biomethanation is sprayed in a controlled manner on sugarcane pressmud. The latter is the filter cake obtained during juice clarification in the manufacture of sugar. Biocomposting is an aerobic, thermophilic process resulting in a product rich in humus which is thus used as a fertilizer. To enhance the efficiency of aerobic systems, several workers have focused on treatment by pure cultures. Further, aerobic treatment has also been examined as a precursor to anaerobic treatment. In studies on both beet spent wash and molasses, aerobic pretreatment of beet spent wash with Penicillium decumbens resulted in about 74% reduction in phenolics content and 40% reduction in colour .

4.2 Physico –Chemical Treatment Methods

Sugarcane molasses spentwash after biological treatment by both anaerobic and aerobic method can still have a BOD of 250–500 mg/l. Also, even though biological treatment results in significant COD removal, the effluent still retains the dark color. The color imparting melanoidins are barely affected by conventional biological treatment such as methane fermentation and the activated sludge process. Further, multistage biological treatment reduces the organic load but intensifies the color due to re-polymerization of colored compounds. In this context, various physico-chemical treatment options have been explored .

4.2.1 Adsorption

Activated carbon is a widely used adsorbent for the removal of organic pollutants from wastewater but the relatively high cost restricts its usage. Decolorization of synthetic melanoidin using commercially available activated carbon as well as activated carbon produced from sugarcane bagasse was investigated by Bernardo et al. (1997). The adsorptive capacity of the different activated carbons was found to be quite comparable.Chemically modified bagasse using 2-diethylaminoethyl chloride hydrochloride & 3-chloro-2-hydroxy propyl trimethyl ammonium chloride was capable of decolorizing diluted spentwash. 0.6 g of chemically modified bagasse in contact with 100 ml spentwash water solution resulted in 50% decolorization after 4 hour contact with intermittent swirling .

4.2.2 Coagulation and Flocculation

Coagulation with alum and iron salts was not effective for color removal. They explored lime and ozone treatment with anaerobically digested effluent. The optimum dosage of lime was found to be 10 g/l resulting in 82.5% COD removal and 67.6% reduction in color in a 30 min period. Almost complete color removal (98%) of biologically treated distillery effluent has been reported with conventional coagulants such as ferrous sulfate, ferric sulphate and alum under alkaline conditions. The best results were obtained using Percol 47, a commercial organic anionic polyelectrolyte, in combination with ferrous sulfate and lime. The combination resulted in 99% reduction in color and 87 and 92% reduction in COD and BOD, respectively.

4.2.3 Oxidation Process

Ozone destroys hazardous organic contaminants and has been applied for the treatment of dyes, phenolics, pesticides, etc. Oxidation by ozone could achieve 80% decolorization for biologically treated spentwash with simultaneous 15–25% COD reduction. It also resulted in improved biodegradability of the effluent. However, ozone only transforms the chromophore groups but does not degrade the dark colored polymeric compounds in the effluent. Similarly, oxidation of the effluent with chlorine resulted in 97% color removal but the color reappeared after a few days. Ozone in combination with UV radiation enhanced spentwash degradation in terms of COD; however, ozone with hydrogen peroxide showed only marginal reduction even on a very dilute effluent .

4.2.4 Membrane Technology

The effluent collected from the distillery industry is highly acidic with pH range of around 3. Hence, it is neutralized using sodium hydroxide. The neutralized solution has a lot of suspended solids, so the filtration is carried out to remove the suspended solids with fine-pore thin cloth or by using some membranes. Therefore, environmental biotechnology today is dominated by attempts to find ways of dealing with growing industrialization and the problems it causes, such as production of toxic wastewaters. Amongst solutions being attempted, bioremediation is the most popular. Bioremediation encompasses all processes that occur in order to transform the environment altered by contaminants back to its original state. The exact processes that can be used to achieve the desired outcomes differ, but they all have the same principle: to use microorganisms and then enzymes they produce to remove contaminants. Therefore bioremediation and waste treatment technologies are gaining momentum .

4.2.5 Evaporation / Combustion

Molasses spentwash containing 4% solids can be concentrated to a maximum of 40% solids in a quintuple- effect evaporation system with thermal vapor recompression. The condensate with a COD of 280 mg/l can be used in fermenters. The concentrated mother liquor is spray dried using hot air at 180 ^{o}C to obtain a desiccated powder with a calorific value of around 3200 kcal/kg. The powder is typically mixed with 20% agricultural waste and burnt in a boiler. The use of Recirculating Fluidized Bed (RCFB) incinerator is recommended to overcome the constraints due to stickiness of spentwash and its high sulphate content. Combustion is also an effective method of on-site vinasse disposal as it is accompanied by production of potassium-rich ash that can be used for land application.

5. REUSE OPTIONS

The wastewaters generated during the distillery and brewery operations contain high organic loads. It has a BOD from 30,000 to 60,000 mg/1. So due to this high organic contents, the wastewaters can be subjected to treatment for the production of biogas, composting, aquaculture and potash recovery .

5.1 Biogas

For the production of biogas from distillery effluent, anaerobic biomethanation of the effluent is adopted, generally. High rate anaerobic technologies are utilized for biogas generation. Fluidised Bed Reactors and Up flow Anaerobic Sludge Blanket (UASB) Reactors are mostly utilized for the production of biogas from the effluents. Some of the biogas production processes being commercial1y established in India at present are:-

5.1.1 Biothane Process:

This process uses the UASB reactor for the production of biogas. This is a stable and automatic process with low operational costs. Before wastewater enters a Biothane UASB treatment process, the wastewater chemistry is optimized in a conditioning tank where the temperature and pH–value are corrected. In the conditioning tank the wastewater will be mixed with recycled, anaerobically treated effluent by means of a recirculation stage and jet mixing. Furthermore, nutrients are dosed, if necessary, to achieve optimal growth conditions for the anaerobic biomass in the Biothane UASB reactor. The conditioned wastewater is then pumped at a constant, continuous flow to the Biothane UASB reactor. A special influent distribution systemensures that the influent is equally distributed over the entire reactor surface area. The influent then passes a dense anaerobic granular biomass bed where the biological conversion process takes place transforming the COD into biogas.

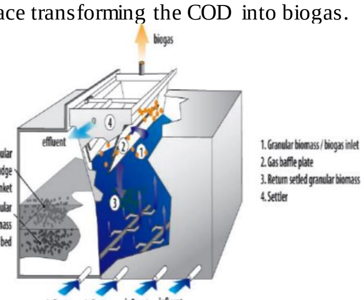


Fig. No: 5.1 Biothane UASB Reactor

The three phase settlers at the top of the reactor separate the treated water from the produced biogas. The biomass settles back to the bottom of the reactor while part of the treated effluent is recycled and returned to the conditioning tank for dilution. Biogas is collected and piped to a biogas treatment step.

5.1.2 Biobed Process: It is similar to Bio thane process. The Biobed EGSB (Expanded Granular Sludge Bed) Technology is extremely efficient due to its advanced and proven process design and its relatively low investment needs in capital and maintenance.

To prepare the industrial effluent for anaerobic treatment, the pH-value and the temperature of the raw wastewater are regulated in a conditioning tank. The wastewater will be mixed inside the conditioning tank with recycled, anaerobically treated effluent for dilution. Nutrients are added, if necessary, to achieve optimal growth conditions for the anaerobic biomass in the Biobed EGSB reactor. In the following treatment stage the conditioned wastewater is pumped at a constant, continuous flow to the tall and slim Biobed EGSB reactor. A special influent distribution system guarantees equal distribution over the entire reactor surface area. The influent then passes a dense and expanded anaerobic granular biomass bed where the biological treatment takes place, converting the COD present in the wastewater into biogas.

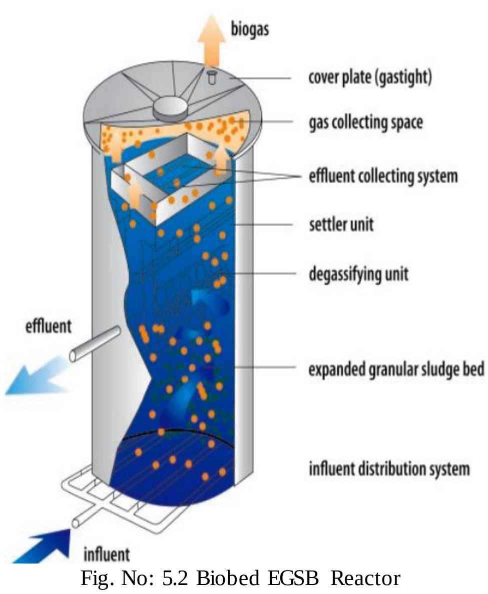


Fig. No: 5.2 Biobed EGSB Reactor

5.1.3 Biopaq Process: In this process anaerobic bacteria are used to treat the distillery effluents for the production of biogas. UASB process is utilized here. The separated sludge in this process makes excellent manure. The generated biogas is used to produce steam for the distillation of alcohol and thus it replaces 50-60% of the total required energy in the process of distillation. For a plant having 40-45,000 kg COD/day 75-80% of COD can be reduced and nearly Rs. 25.50 lakhs can be saved annually for a distillery having 300 working days in a year. The generated biogas from UASB reactor of BioPaq process can be collected and be used as a fuel in gas/dual engine. Through suitable coupling the engine can be coupled with the A/C generator for generation of electricity from biogas. For a 45 klpd distillery 11 KV of power is generated which is then utilized in the distillery thus cutting down the power consumption.

5.2 Composting

In this process, press mud generated from sugar mill is utilised to produce compost by mixing distillery effluent. Both anaerobic and aerobic composting systems are practiced. In some plants composting with treated effluent treated through bio-methanation plant is also practiced. This system can achieve zero effluent if the press mud quantity matches with the effluent generated .

5.3 Potash Recovery

It is done by incinerating the distillery spent wash. In this process, the raw distillery spent wash is first neutralized with lime and filtered. This is further concentrated to about 60% solids in multiple-effect forcer circulation evaporators. Now this thick liquor from the evaporator is burnt in an incinerator and is converted into ash. The dry solids of the spent wash in the form of coke in the incinerator has an average calorific value of 2 Kcal/kg, which is sufficient for supporting self-combustion of the thick liquor in the incinerator. The resulting ash is found to contain about 37% of potash as potassium oxide on an average. This ash is further leached with water to dissolve the potassium salts. Then it is neutralized with sulphuric acid and is evaporated. The potassium salts are crystallized in a crystal1izer. The crystallized mixed potassium salt contains 73.5% of potassium sulphate (K_2SO_4) 16.5% potassium chloride (KCl .) and 5% of sodium salts. It is estimated that a distillery discharging about 300 m^3 of spent wash per day could recover 3 tonnes of Potassium as Potassium oxide or about 5.34 tonnes of Potassium sulphate and 1.2 tonnes of Potassium chloride per day. This potassium is used as a fertilizer.

5.4 Distillery Wastewater Utilisation In Agriculture

Being very rich in organic matters, the utilisation of distillery effluents in agricultural fields creates organic fertilization in the soil which raises the pH of the soil, increases availability of certain nutrients and capability to retain water and also improves the physical structure of soil. Mostly the distillery wastewaters are used for pre-sowing irrigation. The post-harvest fields are filled with distillery effluents. After 15-20 days, when the surface is almost dried, the fields are tilled and the crops are sown and subsequent irrigation is given with fresh water. However, the effluent is diluted 2-3 times before application on crops. Apparently, the irrigation with distillery wastewater seems to be an attractive agricultural practice which not only augments crop yield but also provides a plausible solution for the land disposal of the effluents. One cubic metre of methanated effluent contains nearly 5 kg of potassium, 300 grams of nitrogen and 20 grams of phosphorus. If one centimetre of post methanation effluent is applied on one hectare of agricultural land annually, it will yield nearly 600 kg of potassium, 360 kg of calcium, 100 kg of sulphates, 28kg of nitrogen and 2 kg of phosphates. The distillery effluent contains 0.6 to 21.5 percent potash as KO (Potassium Monoxide), 0.1 to 1.0 percent phosphorus as PO (Phosphorus Monoxide) and 0.01 to 1.5 percent Nitrogen as N_2 .

5.5 Recommendations

Reviewing the magnitude of pollution potential of distillery wastewaters and the experiences gained over years on recovery of residues and treatment of wastewater the following recommendations are made :

- For recovery from the treatment of distillery spentwash, depending on the availability and cost of land in a particular area, simple treatment in anaerobic lagoon to generate biogas followed by treatment in aerated lagoon or oxidation ditch may be considered. Where the availability and cost of land are the main constraints, activated sludge type of aeration treatment in a deep oxidation ditch would be more economical than the conventional or extended aeration sludge process.

- For the treatment of distillery spent wash, removal and/or recovery of yeast should be prerequisite to reduce the load and eliminate certain undue problems in the waste treatment/recovery plants. This recovered yeast can be utilised as a good cattle feed. Recovery of spent grains and yeast and their utilisation as animal feed and feed supplement might be encouraged not only for reducing the pollution load form the wastewaters but also in providing for a reasonable return on their capital investment of the industry.

- Where the availability of land is a severe constraint, evaporation and incineration of distillery spent wash to recover potash would appear to be the only choice. In spite of high capital investment required for such type of plants, heat recovery would defray significantly the organisation and maintenance costs and contribute towards conservation of energy.

- In the countries like ours, where indigenous sources of potash are scarce or not available, recovery of potash from crude ash by evaporation and incineration of spent wash would appear to be an economically attractive alternative. If heat recovery is simultaneously used, the pay back period of the plant can be substantially reduced.

- Anaerobic digestion of spent wash in a closed digester followed by its treatment under an activated sludge process, especially in an oxidation ditch to reduce costs, might be adopted as the most cost-effective system for the distilleries which are located away from sugar factories. Moreover, the treated effluent can be conveniently used for irrigation of cane fields or other crop lands, subsequently.

- Biogas generated from the distillery effluents, can be effectively utilized in production plant boilers thus saving about 50 to 60 percent fuel/steam. The treated effluent having almost all the potash retained in it may be utilised for irrigation purposes.

- The utilisation of the distillery effluent in agricultural fields will not only enrich these further with essential plant nutrients like nitrogen, phosphorous and potash but also compensate the expenditure on fertilizers for crop growth. This practice will result in revenue generation and further lead to offsetting the costs substantially.

- Similarly spentwash utilization in bioearth composting, where adequate land is available, being a simple process and not involving any heavy machinery is also one of the cost effective methods of disposal. Moreover it is feasible alternative for utilization of treated effluent; as the same generates revenue thus offsetting the costs and further leading to reduction in pay back period.

6. CONCLUSION

Industries using large quantities of water as distilleries, it is essential to treat and reuse their waste water. It has been observed that Physico-Chemical methods are capable of both organic and colour reduction. Whereas, Biological treatment, especially with pure cultures, appears promising and cost-effective for colour removal. Further the emerging new treatment methods like enzymatic treatment have technological advantages and yet are in its infancy, requiring economical considerations in order to apply it on the plant scale. The cost of effluent treatment in distilleries is likely to be compensated substantially by availability of methane gas. If all the distilleries present in India resort to biomethanation, then approximately 2.0 million cubic metres of biogas shall be generated per day, with a calorific value of approximately 5000 Kcal/m. This is equivalent to saving of 2240 tonnes of coal per day, in turn avoiding CO of about 3100 tonnes per day. And also a good revenue from it. It has to be stressed that recovery from the distillery effluents is a better way to reduce the cost of wastewater treatment for decreasing its pollution level which is actually a very costly affair. It has been elucidated during the study that several technological options that are available in our country need to be exploited to the maximum so that, this will help to control the pollution created by the distillery wastewaters and also enable to derive by-products which are commercially beneficial .

7. REFERENCES

1. K. Rani, V., et al. (2013) "Biological Treatment of Distillery Wastewater' – An Overview", *International Journal of General Engineering and Technology (IJGET)*, Vol. 2, pp.15-24 .

2. Lekshmi.S.R (2013) "Treatment and Reuse of Distillery Wastewater", *International Journal of Environmental Engineering and Management*, Vol. 4, pp. 339-344 .

3. Lt. Col. Mantha Nagaraj, Dr. Arvind Kumar (2008) "Distillery Wastewater Treatment And Disposal", *Scribd*, Vol. 1, pp. 1-10 .

4. Pawar Avinash Shivajirao (2012) "Treatment of Distillery Wastewater Using Membrane Technoloies", *International Journal of Advanced Engineering Research and Studies (IJAERS)*, Vol. 1, pp. 275-283 .

5. R. Moletta (2005) "Winery and Distillery Wastewater Treatment by Anaerobic Digestion", *Water Science and Technology*, Vol 51, pp 137–144 .