ALKALINE MOLARITY RATIO FOR SUSTAINABLE DESIGN OF BUNKER USING GEOPOLYMER CONCRETE - A GREEN CONCRETE APPROACH

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Abstract
The project involves the Planning, Analysis and Design of a Bunker. The analysis and design involves planning and drafting, structural analysis, load calculation, design calculation, and checking done by modelling using STAAD-Pro V8i, the manual design of vertical slab , design of columns, the design of beams and design of footing is done by limit state method as per Indian standard. Analysis has been done for various load combinations including seismic load, wind load, etc, as per the Indian Standard Code of Practice.Theprojectinvolvesacomparisonbetweenreinforcedconcreteandgeopolymer concrete. Finally, Estimation and costing are done as per the schedule ofrates.

Key words : Geopolymer concrete, sustainable , Bunker, Green concrte

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1 INTRODUCTION

Bunkers and silos are structures that are used as storage tanks. The structural design of bunkers with the procedure and design considerations are discussed. The bunkers and silos made of reinforced concrete have almost replaced the steel storage structures. Concrete bins possess less maintenance and other architectural qualities greater than steel storage tanks. They are used to store materials like grain, cereals, coal cement etc. They both serve the purpose of bins. The concept and difference between bunkers and silos are explained in the following sections: Bunkers are mainly employed for the storage of underground dwellings. These are mainly related to emergency conditions duringwars.

The main two characteristics that make a bin act as a bunker is based on the

- Depth(H)
- Angle ofrupture

These are characterized as shallow structures. The angle of rupture of the material in case of bunkers, will meet the horizontal surface at the top of the bin, before it touches theoppositesidewallsofthestructureasshowninthefigure.Bunkersmaybecircular or rectangular (or square) inplan.

The main structural elements that constitute a bunker. They comprise of

- Verticalwalls
- HopperBottom
- Edge Beam (At the toplevel)
- Supporting Columns

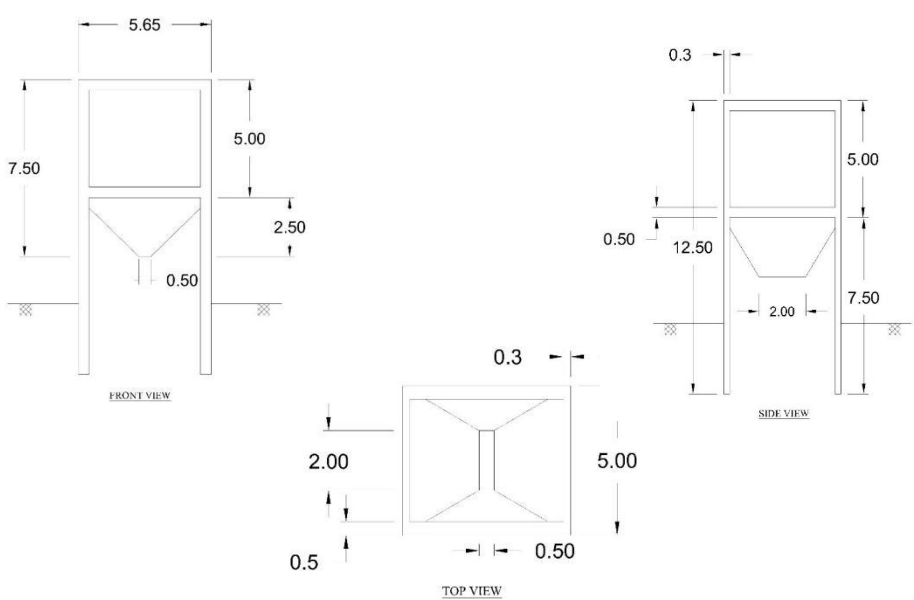
2 OBJECTIVES

- To plan, analyze and design a bunker using geopolymerconcrete
- To find an alternative for OPCconcrete.
- To provide high-strength geopolymer concrete than ordinary Portlandconcrete.
- Tocalculatetheoptimumdesignmixofgeopolymerconcreteforstoragestructures.

3 SCOPE

- To design a durable and sustainable infrastructure for storage using geopolymer concrete.
- Providingaviableuseforwastematerialswhichareoftendisposedofinlandfills.
- Better thermal insulationproperties
- To make emission-less transparentconcrete.
- To make economical and eco-friendlyconcrete.

4 DESIGN OF BUNKER



All dimensions in mm

Figure 1: design details of bunker

5 LOADCONDITION OF BUNKER

Dead Load:

Dead loads shall include the weight of all structural components such as beams, , columns and walls and other permanently applied external loads. In solid storage structures, the dead loads shall be calculated by taking the weight of the components such as ring beams, stiffeners, internals and shell. The dead loads are static forces exerted in the vertical plane and are relatively constant throughout the lifetime. The building materials are not considered dead loads till they are constructed in the position permanently. The unit weight of the building materials, parts and components are given in the Indian Standard IS 456 – 2000 "Code of Practice for Design loads for buildings and structures".

Live Load:

Live loads are temporary loads which occur over a short duration of time. The imposed loads are produced by live loads, dust loads, minor equipment loads, erection loads, operation/maintenance loads and loads produced by personnel, tools, and other items placed on the structure, but not permanently attached to it. The floor live loads and roof live loads are to be taken for the load calculation of the solid storage structure. Unless specified otherwise, the minimum live load values are to be considered as per the IS specifications

Seismic Load:

The inertia force created by ground accelerations during an earthquake result in seismic loads. The application of earthquake-generated agitation to the building structure is the concept of seismic load. The mass of the building, the dynamic properties, intensity, duration, and frequency of the ground motion are the functions on which the magnitude of loads depends. The national building codes prescribed the requirements of buildings under seismic performance. Seismic analysis for the foundation of solid storage structure is determined as per IS 1893 – 2002 "Criteria for Earthquake resistant design of structures. The seismic pressure on the solid storage structure walls is calculated as per the guidelines for calculations of seismic actions provided by Indian standards.

Load combination (as per IS 456:2000):

More than one type of load that acts on the structure will result in the load combination. The load combination is to be calculated for the structure that contains more than one type of loading. As per the Building codes, the safety of the structure is ensured by specifying the load combinations with the factors

1.5(DL+LL)

1.5(DL+WL)

1.2(DL+LL+SL)

1.2 (DL+LL+WL)

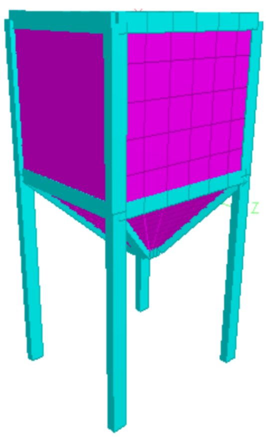
(0.9 X DL + 1.5 X SL)

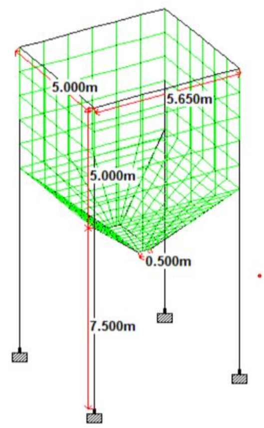
(O.5 X DL + 1.5 WL)

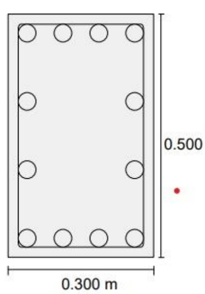
6 STRUCTURAL MODELLING

The bunker is modelled in STAAD PRO software as 3-D SPACE FRAME. Joint Co-ordinates, Member Incidences, Member Property, and Supports are defined in STAAD INPUT. The calculated loads are applied under individual load cases followed by Load Combination specified as per IS 456: 2000

Figure 2: structural detailing of bunker

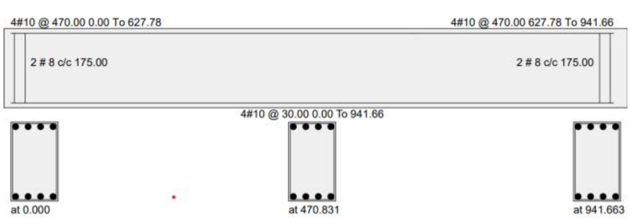






Design Parameter

Fy(Mpa)	415.000000
Fc(Mpa)	30.000000
Depth(m)	0.500000
Width(m)	0.300000
Length(m)	0.941663



Fy(Mpa)	415
Fc(Mpa)	30
As Reqd(mm²)	1200.000000
As (%)	0.905000
Bar Size	12
Bar No	12

7. Mix design

STEP 1: Fix the Alkaline Activator Solution (AAS) Content

From the trials carried out in the laboratory it was found that at an AAS content of 200 kg/m3 GPC can be developed effectively with better strength, workability, and economy.

STEP 2: Determination of Strength

Fck = fck + (1.65* 5)

= 35 +8.25

Fck = 43.25 Mpa

AAS/FA ratio is 0.4

STEP 3: Calculation of Binder Content

Binder content (BC) = AAS content / (AAS/FA)

BC = 200 / 0.4 = 500 kg/m^3

STEP 4: Calculation of individual activator solution contents

For all the mixes the Na2SiO3 and NaOH ratio employed was 1.5, and R shall be taken as 1.5.

Mass of AAS = Mass of NaOH (1.5 + 1)

Mass of NaOH (M_{NaOH}) = Mass of AAS/2.5

= 200/2.5 = 80 kg/m^3

Mass of Na2SiO3 ($M_{Na2SiO3}$) = 1.5 x M_{NaOH}

= 1.5 x 80 = 120 kg/m^3

STEP 5: Calculation of Water Content in AAS

Mass of water in NaOH = M_{NaOH} (1 - S_{NaOH})

= 80 (1- 0.455) = 80 (0.545) = 43.6 kg/m^3

Mass of water in Na2SiO3 = $M_{Na2SiO3}$ (1 - $S_{Na2SiO3}$)

= 120 (1 – 0.345)

= 120 (0.655) = 78.6 kg/m^3

Total Water Content (Wc) in the mix = Mass of water in (NaOH + Na2SiO3)

= 43.6 + 78.6 = 122.2 kg/m^3

Total solid content = 500+36.4+41.4

= 577.8 kg/m^3

Water to geopolymer solid ratio =Total water content/ Total solid content

= 122.2/ 577.8 =0.21

STEP 6: Determination of Total Aggregates

The volume of total aggregates (VTA) is obtained by using the absolute volume method as follows:

VTA = 0.98 – [{(Bc/GB) + (M_{NaOH}/G_{NaOH}) + ($M_{Na2SiO3}$ /$G_{Na2SiO3}$)} x {1/1000}]

= 0.98 – [{(500/2.2) + (80/1.4506) + (120/1.35)} x {1/1000}]

= 0.98 – 0.371 = 0.609 m^3

STEP 7: Calculation of Fine and Coarse Aggregate Content

Mass of fine aggregate (MFA) = (30% x VA) x GFA x 1000

= (20% x 0.654) x 2.63 x 1000

= 480.501 kg/m^3

Mass of 20mm aggregate (M20) = (33% x VA) x G20 x 1000

= (28% x 0.654) x 2.73 x 1000

= 548.65kg/m^3

Mass of 12.5mm aggregate (M12.5) = (32% x VA) x G12.5 x 1000

= (37% x 0.654) x 2.76 x 1000

= 621.91kg/m^3

STEP 8: Superplasticizer (SP) Dosage

Based on the experimental observations in the laboratory, SP dosage of 1% of binder content is found to be suitable to improve the workability and the same has been followed in this case.

SP Dosage = 1% x 500 = 5 kg/m3

Binder	FA (Kg/m^3)	CA (20 mm) (Kg/m^3)	CA (12.5mm) (Kg/m^3)	NaOH (Kg/m^3)	Na2SiO3 (Kg/m^3)	Water	SP (Kg/m^3)
500	480.5	548.65	621.9	36.4	41.4	122.2	5
1	0.961	1.097	1.244	0.073	0.083	0.25	0.01

8. Comparison between 10 M and 12 M (Molarity)

Molarity = 10M

NaOH =10*40 =400

Mass of NaOH (M_{NaOH}) = 200/1000*400 = 80 kg/m^3

Mass of Na2SiO3 ($M_{Na2SiO3}$) = 1.5 x M_{NaOH}

= 1.5 x 80 = 120 kg/m^3

Molarity = 12M

NaOH =12*40 =480

Mass of NaOH (M_{NaOH}) = 200/1000*480 = 96 kg/m^3

Mass of Na2SiO3 ($M_{Na2SiO3}$) = 2.5 x M_{NaOH}

= 2.5 x 80 = 240 kg/m^3

9. CONCLUSION

In this project, we have analysed and designed a durable sustainable bunker for storage purposes. Structural elements like beams, columns, vertical slabs, and footing. are designed by the limit state method. It provides better thermal insulation properties. The structure was durable and sustainable (resistance against chemical attack). Also, it makes economical and eco-friendly concrete. We have also done the analysis of various load combinations as per the Indian Standard Code of Practice and estimation, costingas per the schedule ofrates.

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