Effect of Plumbing System in Construction

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Abstract
The impact of the plumbing system during construction is significant. Every home or structure must have a plumbing system. The plumbing system must be planned and designed properly in order to meet the residents' needs for hygiene. According to reports, plumbing and sanitary work account for 12 to 15% of a building's construction costs. Installation, repair, maintenance, and service of plumbing fixtures and fittings are all part of a plumber's job description. A plumber should be diligent, have excellent communication skills, be a results-oriented worker with a positive attitude, and have a solid understanding of the processes needed to complete various tasks. Plumbing and sanitary systems are necessary for any structure to operate correctly, whether it is residential, commercial, or industrial. Therefore, it is crucial to have a consistent and ample water supply as well as an appropriate method for disposing of waste water. All sorts of building construction heavily relies on plumbing and pipe fittings. An effective plumbing system ensures improved sanitation and keeps the air fresh. To prevent physical interferences between mechanical, electrical, and structural or architectural characteristics, it is essential to choose a competent plumbing system. A good plumbing system will lessen plumbing emergencies, lower maintenance and construction costs, and shorten the design process. We can reduce the cost of a construction by performing various load calculations that take into account different plumbing systems.
Keywords— Effect of Plumbing systems, Construction, Load, Maintenance etc.

1. Introduction

Each and every home or structure needs plumbing. The plumbing system must be planned and designed properly in order to meet the users' needs for hygiene. Plumbing work is estimated to account for 12 to 15 percent of construction costs. Plumbing system installation, repair, upkeep, and maintenance are all part of a plumber's job description. A plumber needs to be well-versed in all aspects of their job, but they also need to be able to communicate clearly and work with a can-do attitude.[1]

Without a reliable plumbing system, no building—residential, commercial, or industrial—can operate as intended. Because of this, it's critical that the sewage system and water supply are both reliable and enough. Plumbing is crucial to the efficient operation of all kinds of structures. A productive pipeline that enhances the environment for future generation[2]

To prevent physical interference with other systems, such as plumbing, fire, electrical, and structural or architectural aspects, it is essential to select an effective plumbing solution. This reduces water damage, maintenance expenses, and construction costs, and expedites planning and execution [3].

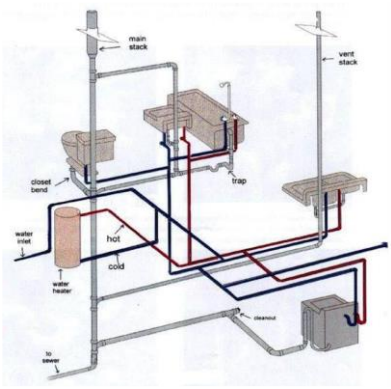

Fig:1: Plumbing system

Different Types of Plumbing System

1. Sunken Plumbing System.
2. Raised Toilet Flooring.
3. Underslung Plumbing System.

- **Sunken Plumbing System :-**

It is the most traditional method of toilet drainage. A sunken slab serves the purpose of hiding all the pipes under the floor. Water pipes are hidden beneath the floor, therefore it's important to take precautions to prevent leaks. It is recessed below the usual floor height. A sunken slab is primarily used to conceal/hide a bath unit's drainage line and floor traps. Sunken slab depth ranges from 200 to 450 millimetres, depending on sanitary fixtures and drainage pipes.

In order to fit floor traps and drainage lines, toilet floors are typically sunken. Floors must be 400–450mm below grade in order to accommodate a floor "p" trap of an approved type. The offset in the toilet is increased since the partition wall is typically flush with the beam on the room side. The ledge wall thickness will then be increased to prevent beam chasing [2]

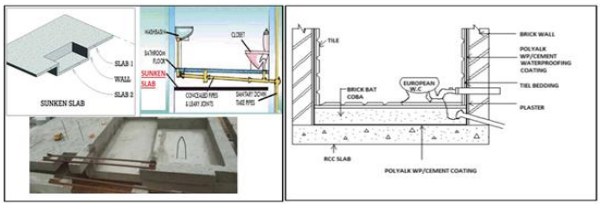

Fig 1 : Sunken Plumbing System

- **Raised Toilet Flooring :-**

In this system, the slab for the toilet is built at the same height as the slabs next to it. To hide all plumbing lines and fittings, the toilet floor level has been raised above the slab. To access the toilet unit, typically a step is erected from the adjacent slab. The raised floor's height can range from 150 millimetres to 400 millimetres depending on the sanitary fitting and drainage pipeline.[3]

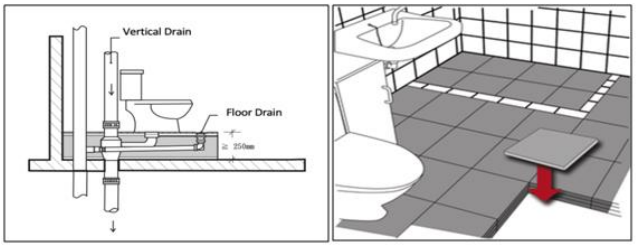

Fig 2 : Raised Floor Plumbing

- **Underslung Plumbing System**

The toilet slab is cast at the same level as the slabs next to it in an underslung plumbing system. Wherever plumbing pipes must travel through the slab, sleeves or holes are pierced, and the pipes are then secured to the slab's underside. The lower floor's artificial ceiling is used to conceal the pipe. Any leaks in this case will drip into the artificial ceiling, making them simple to find and fix. Without causing any damage to the building, the complete plumbing system can be replaced if necessary. As opposed to the previous two systems, this system is affordable and simple to maintain [2]

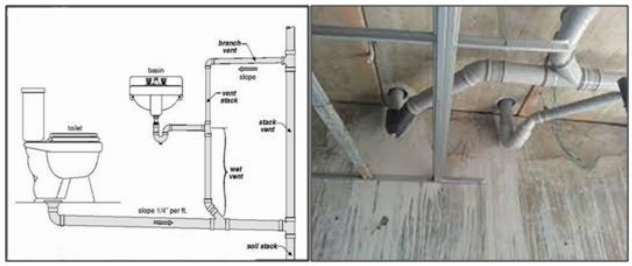

Fig 3 : Underslung Plumbing System

The issues for the project are listed below.

- Raised toilet floor and a sinking plumbing system increase dead load.
- To lessen the noise while using the bathroom, appropriate acoustic pipe insulation or acoustic fittings are required. The price of the underslung system rises as a result.
- Sunken Slab systems demand specialised labour and additional time to construct the slab, waterproofing, and cuva.
- An elevated toilet floor Unsuitable for usage by the elderly.
- With underslung toilet system To lessen noise when using the loo, you need specialised acoustic pipe insulation or acoustic connectors. This drives up the price of the system.

2. Problem Definition

Water is made available to the public by the plumbing system for their health, hygiene, and general wellbeing. We often take for granted having access to clean, convenient water because of plumbing. Water sustainability requires increased plumbing efficiency. When making plans for a quality build, plumbing must be taken into account.

The National Plumbing Code has established a set of guidelines that apply to the planning and design of plumbing systems. However, the Code does not mandate a set standard design for the pipe system, more specifically, the positioning and placement of the different plumbing fixtures. And when considering the endless design options for these fixtures, consider the various plumbing system design options as well. While we adhered to the National Plumbing Code's health and safety regulations, there are unending design possibilities from diverse designers. There is a great deal of design flexibility in how the plumbing is routed, where the outlets and cleanouts are located, and other associated installations.

3. Proposed System

Access to water for human health, hygiene, and wellbeing is made possible through the pipe system. We frequently take for granted the clean, convenient water that plumbing makes possible. Water conservation requires improving the efficiency of water pipes.

A smart construction plan must take the plumbing into account. Although the majority of people are

unaware of it, plumbing is a crucial component of every enterprise or building project. Total project costs for the construction project include 12–15% for pipework.

We can prevent physical interference between MEP systems and structural or architectural components by deciding on affective Plumbing. It aids in enhancing our structured lives. It also cuts down on planning and execution expenses. By performing various load estimations while taking varied pipework into consideration, we may reduce the design's cost.

In Underslung Plumbing System :

- The toilet slab is made of the same material as the slabs adjacent to it.
- Plumbing pipes are attached to the underside of the slab by piercing sleeves and cut-outs wherever they must pass through it.
- Any leaks, which are hidden above the false ceiling from the base of the slab, will drip into the fake ceiling where they may be promptly detected and remedied. If necessary, the entire plumbing system can be replaced without harming the structure.
- It also lowers the price of the brick bat cuba and reduces the dead load on the building.

4. Methodology

- ***Flowchart of system***

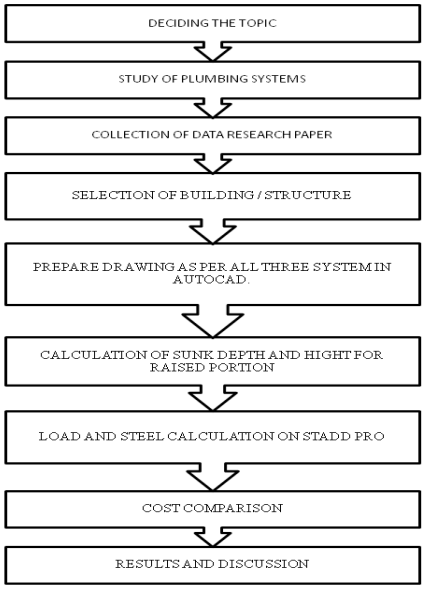

Fig.4. Working Methodology

- ***Comparisons of plumbing system:***

Theoretical comparison of these three types of plumbing system has been done on the basis of various literatures and data available from various sources.

Sunken plumbing	Raised toilet flooring	Under slung plumbing system
Sunk in slab required.	Required raised portion.	No need of sunk or raised in portion.
Pipe line is concealed.	Pipe line is concealed.	Pipe line is not concealed.
Special material will be required to fill sunk slab.	Special material will be required to build raised portion.	No need f any special material pipeline is hide under false celling.
Difficult to identify leakages.	Difficult to identify leakages.	Leakages can be identified easily.
Duration of execution will be more.	Duration of execution will be more.	Duration of execution can be reduced.
Difficult for maintenance.	Difficult for maintenance.	Easy to maintenance.
Increase dead load due to coba filling.	Increase dead load due to brick bat coba filling.	Reduce dead load.

- ***Calculation for sunk/raised portion***

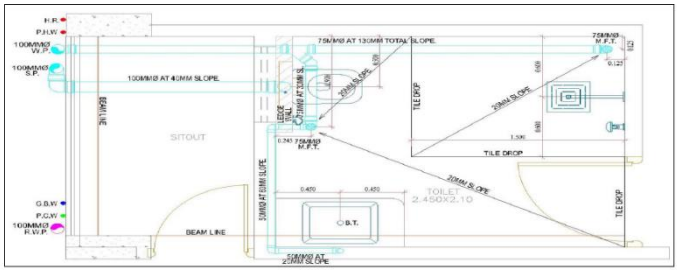

Fig.5.Plan of toilet as per sunken and raised toilet flooring system.

- ***Consideration***

1. Floor Finish Level = 50mm
2. Slope ratio

a. For 100mm dia. = 1:40

b. For 75mm dia. = 1:30

(Above consideration of slope ratio is as per BIS 2016 PART 9)

a. For 100mm dia. Pipe

= Dia. of Pipe + Slope + Floor Finish

= 100 + 40 + 50

= 190mm ~ 200mm

b. For 75mm dia. Pipe

= Slope + Depth of Trap + Floor Finish

= (30+130) +110+50

= 320mm ~ 350mm

Sunk/Raised portion is considered as larger value from “a” and “b”.

Hence, required sunk/raised portion = 350mm

- ***Modeling, Analysis & Design of building on STADD PRO for building having underslung plumbing system***

Design Considerations: -

- Total Stories Number = G +4
- Height Of Each Floor = 3.3 Meter
- Total Height of Building = 19 Meter
- Slab Thickness =150.00 MM
- External Wall Thickness = 230.00 MM
- Internal Wall Thickness = 115.00 MM
- Grade of concrete = M25
- Grade of steel = Fe500
- Beam Size = i. 230 MM X 600MM
  ii. 230MM X 450MM
- Column Size = i. 230 MM X 600MM
  ii. 230 X 450MM
- Loads: -

1. Dead load
2. Live load
3. Load combinations

a. 1.0 (DL + LL)
b. 1.5 (DL + LL)

- ***Modeling of building having underslung plumbing system on STADD PRO***

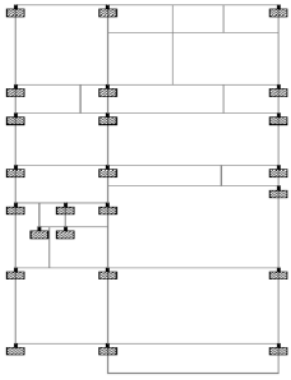

Fig.6.Top view of structure (design for Underslung)

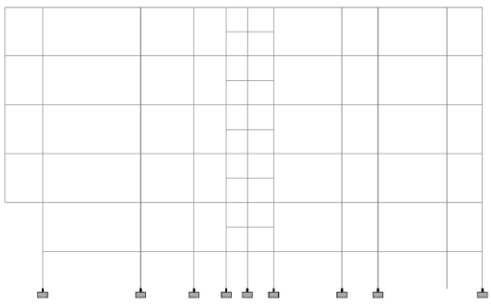

Fig.7.Sideview of structure (design for Underslung)

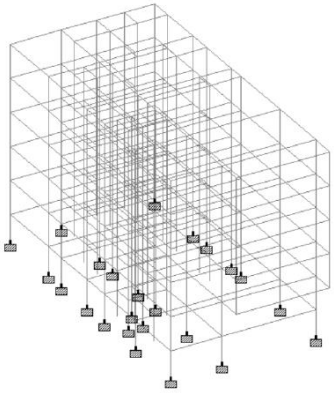

Fig.8.Isometric view of structure (design for Underslung)

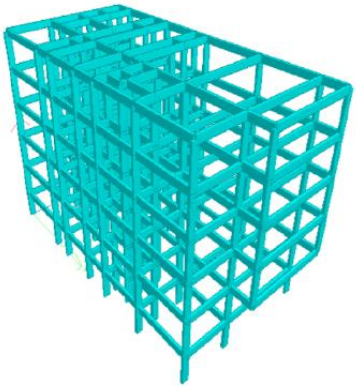

Fig.9.Isometric view of structure (design for Underslung)

- ***Analysis of building having underslung plumbing system on STADD PRO***

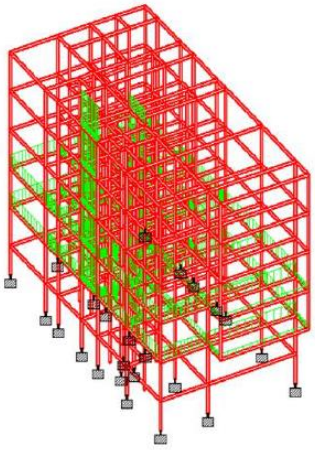

Fig.10. Application of load on structure(design for Underslung)

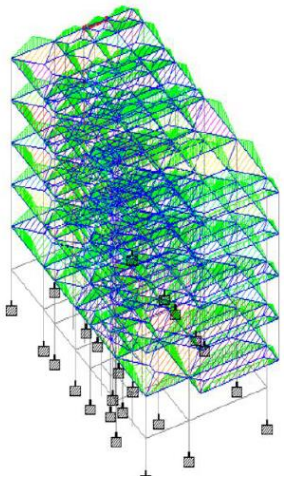

Fig.11.Bending moment and share force(design for Underslung)

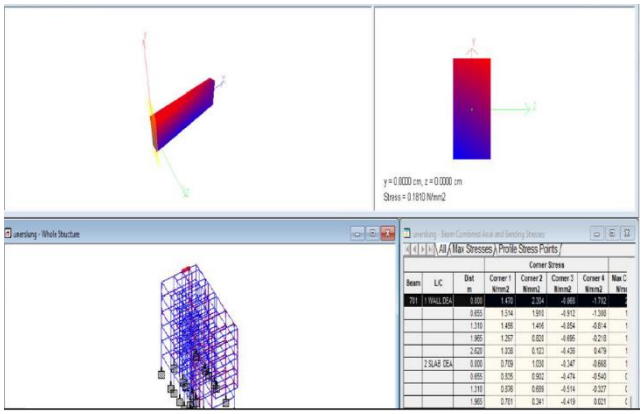

Fig.12.Stresses in beam (design for Underslung)

- ***Design of building having underslung plumbing system on STADD PRO.***

```
  TOTAL UNFACTORED WEIGHT OF THE STRUCTURE =              6144.499 KN
  TOTAL UNFACTORED WEIGHT OF THE STRUCTURE APPLIED =      6057.113 KN



51. START CONCRETE DESIGN
52. CODE INDIAN
53. FC 25000 ALL
54. FYMAIN 500000 ALL
55. FYSEC 500000 ALL
56. DESIGN BEAM 113 TO 120 122 TO 146 148 TO 167 170 TO 177 179 180 225 TO 258 -
57. 260 TO 289 291 292 337 TO 370 372 TO 401 403 404 449 TO 482 484 TO 513 515 -
58. 516 561 TO 594 596 TO 625 627 628 673 TO 706 708 TO 737 739 740 747 749 751 -
59. 753 755
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Fig.13.Total load on structure after analysis(design for Underslung)

- ***Design of building having underslung plumbing system on STADD PRO.***

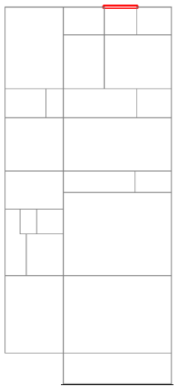


Fig.14.Rcc design(design for Underslung)

BAR DIA (in mm)	WEIGHT (in New)
8	66809
10	14740
12	100463
16	13682
20	2448
25	569
*** TOTAL=	198711

252. FINISH

********** END OF THE STAAD.Pro RUN **********

**** DATE= MAR 11,2023 TIME= 0:43: 2 ****

Fig.15.Total steel for Underslung

- ***Toilet design as per sunken plumbing system and Raised toilet flooring.***

• Consider slope ratio: - 1:100

• 350mm sunk or raised portion will be required

• Gravity based system is used

• Required consideration made by using BIS 2016 PART 9

• Drawing made by using AutoCAD software

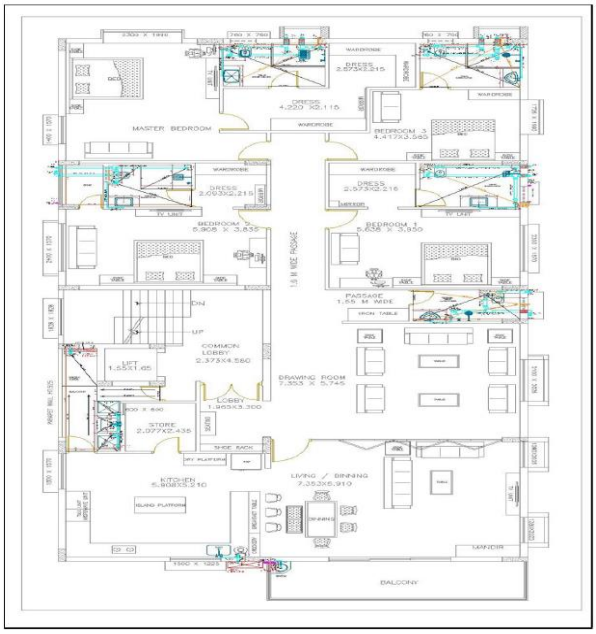


Fig.16.Toilet design as per sunken plumbing system and Raised toilet flooring.

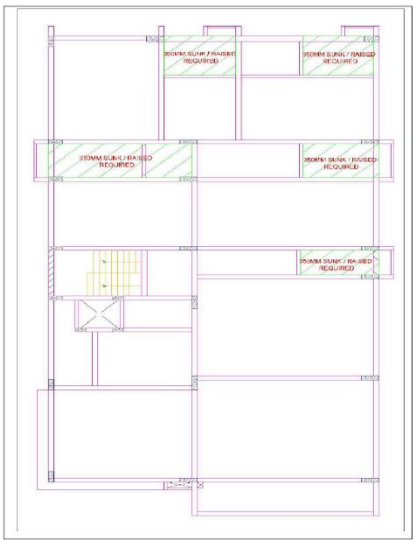


Fig.17.Sunkand raised portion marking.

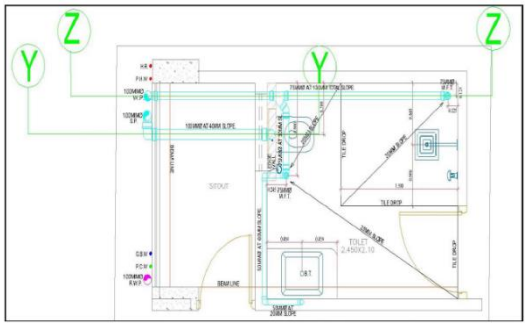


Fig.18.Single toilet as per sunken plumbing system and Raised toilet flooring.

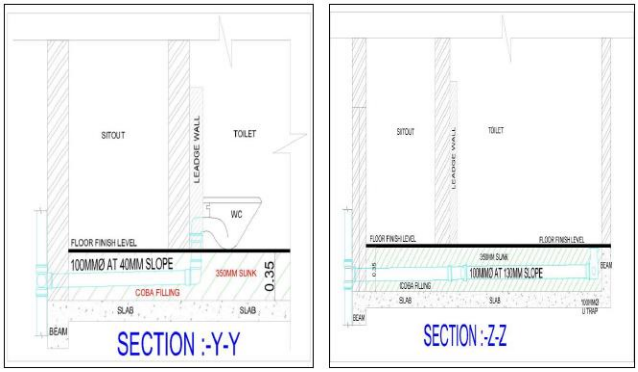


Fig.19.Section details for sunken plumbing system and Raised toilet flooring.

- ***Modeling, Analysis & Design of building on STADD PRO for building having sunken toilet plumbing and raised toilet flooring.***

• Total Stories Number = G +4
• Height Of Each Floor = 3.3 Meter
• Total Height of Building = 19 Meter
• Slab Thickness =150.00 MM
• External Wall Thickness = 230.00 MM
• Internal Wall Thickness = 115.00 MM
• Concrete & Steel Grades =M25 & Fe500
• Beam Size = 230 MM X 600MM
• Column Size = 230 MM X 600MM

Loads: -
1. Dead load
2. Live load

Load combinations a.1.0 (DL+ LL)
b. 1.5 (DL+ LL)

- ***Modeling of building having sunken toilet plumbing and raised toilet flooring on STADD PRO.***

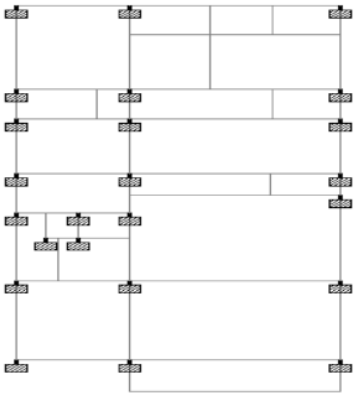


Fig.20. Top view of structure (design for sunken toilet plumbing and raised toilet flooring.*)*

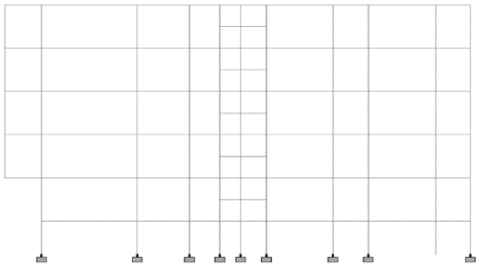


Fig.21.Top view of structure (design for sunken toilet plumbing and raised toilet flooring.*)*

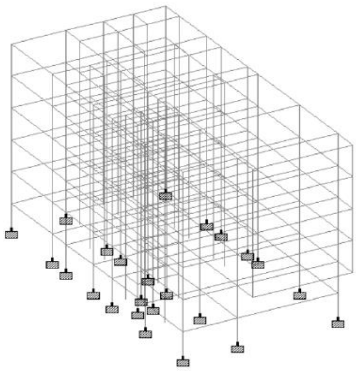


Fig.22.Isometric view of structure (design for sunken toilet plumbing and raised toilet flooring.)

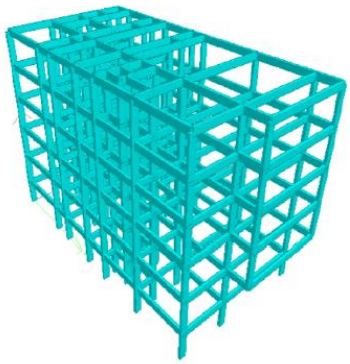


Fig.23.Isometricview of structure (design for sunken toilet plumbing and raised toilet flooring.)

- ***Analysis of building having sunken toilet plumbing and raised toilet flooring on STADD PRO.***

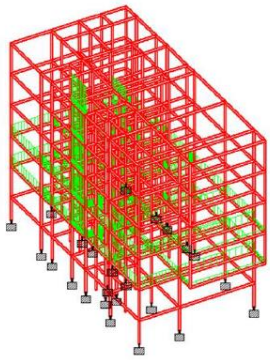


Fig.24.Application of load on structure definition(design for sunken toilet plumbing and raised toilet flooring.)

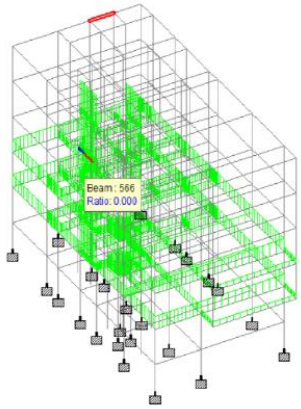


Fig.25.Bending moment and share force(design for sunken toilet plumbing and raised toilet flooring.)

- ***Design of building having underslung plumbing system on STADD PRO***

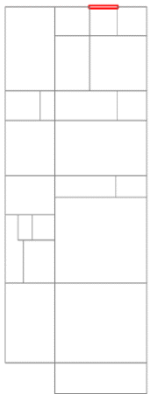
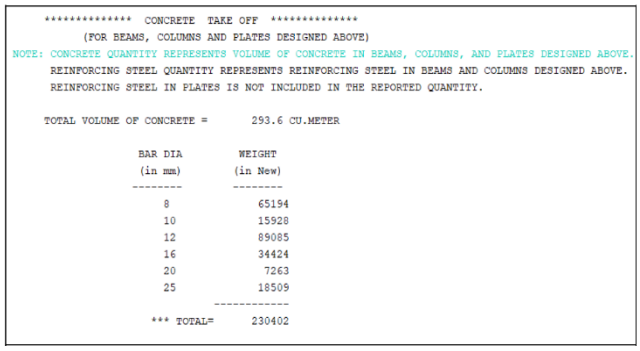


Fig.26.RCC design(design for sunken toilet plumbing and raised toilet flooring.*)*



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************** CONCRETE TAKE OFF **************
(FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)
NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.
REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.
REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

TOTAL VOLUME OF CONCRETE =       293.6 CU.METER

          BAR DIA          WEIGHT
          (in mm)          (in New)
          --------         --------
             8               65194
            10               15928
            12               89085
            16               34424
            20                7263
            25               18509
                            ------------
        *** TOTAL=          230402
```

Fig.27.Total steel for sunken toilet plumbing and raised toilet

5. Result & Discussion

Following results have been discovered after modelling, analysing, and designing a structure using STAAD PRO while taking into account three plumbing systems, and the following comparison has been made using the STTAD pro analysis and design report.

- ***Comparison of dead load on structure.***

Table 1: - Dead load on structure

SR. NO	PLUMBING SYSTEM	LOAD ON SRUCTURE (KN)
1	SUNKEN PLUMBING SYSTEM	13974.836
2	RAISED TOILET FLOORING	13974.836
3	UNDERSLUNG PLUMBING SYSTEM	12202.612
DIFFERENCE		**1773.224**

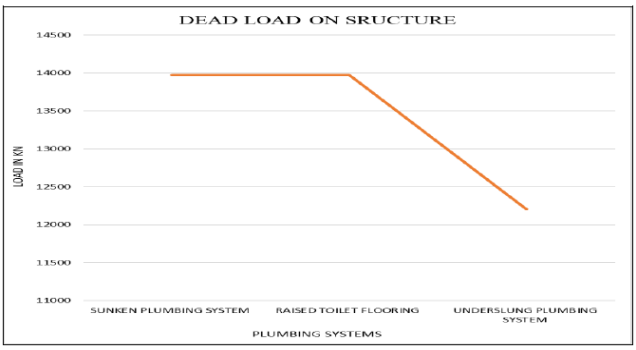

Fig.28.Dead load on structure

After analysing the structure using STAAD PRO for all three plumbing systems, it was discovered that the usage of an underslung plumbing system results in a lower dead load on the structure than that of a sunken plumbing system or a raised toilet flooring system.

- **Comparison of bending moment and share force**

Table 4.Comparison of bending moment and share force

Beam no.	Sunken plumbing system		Raised toilet flooring		Underslung plumbing system	
	Shear Force	Bending Moment	Shear Force	Bending Moment	Shear Force	Bending Moment
144	-223.602	-329.848	-223.602	-329.848	-149.068	-219.899
146	69.4	102.422	69.4	102.422	46.267	68.281
143	53.307	16.204	53.307	16.204	35.538	10.802
128	163.132	273.109	163.132	273.109	108.755	182.073
152	20.874	11.783	20.874	11.783	13.916	7.855
151	-63.535	-105.573	-63.535	-105.573	-42.357	-70.382
129	202.681	138.111	202.681	138.111	135.12	92.074
150	-160.377	-227.284	-160.377	-227.284	-166.918	-151.523
120	15.561	17.43	15.561	17.43	10.374	11.62
136	93.566	129.874	93.566	129.874	62.377	86.583
155	-0.541	-0.583	-0.541	-0.583	-0.36	-0.388
135	101.363	143.651	101.363	143.651	67.575	95.767
158	-0.678	-1.434	-0.678	-1.434	-0.452	-0.956
157	-179.932	-273.307	-179.932	-273.307	-119.955	-182.204
130	60.875	113.21	60.875	113.21	40.583	75.473
156	-155.858	-221.284	-155.858	-221.284	-103.905	-147.523
172	11.467	5.361	11.467	5.361	7.845	3.574
164	194.842	285.08	194.842	285.08	129.895	190.054
132	11.496	13.107	11.496	13.107	7.664	8.738
170	-164.821	-256.634	-164.821	-256.634	-109.88	-171.089

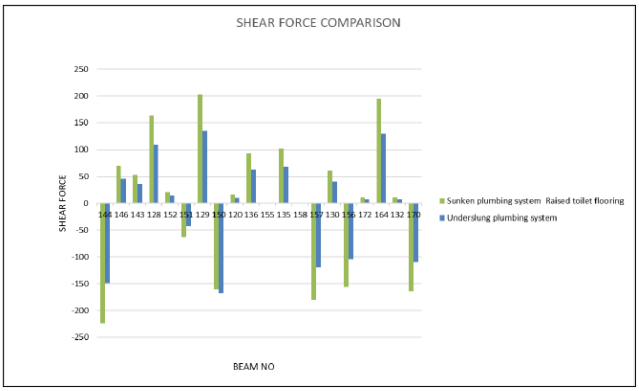

Fig.29.Comparison of share force

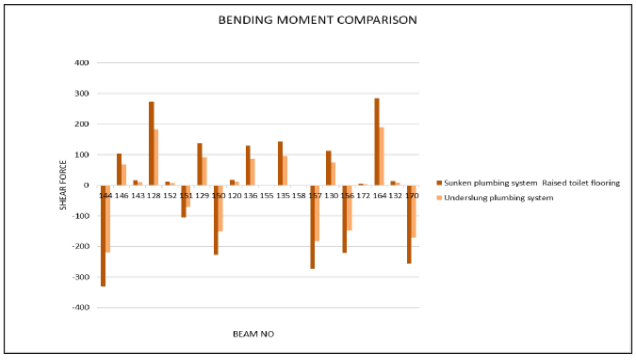

Fig. 30. comparison of bending moment

Figures 29 and 30 illustrate the bending moment and share force in a beam graphically. When comparing bending moment and share force, just the beam at the toilet slab has been taken into account because only the toilet area is equipped with a sunken slab and elevated section.

- ***Comparison of quantity of material require.***

Three plumbing systems were designed using RCC on a structure using STTAD Pro, and the amount of materials needed for construction are displayed below,

Concrete

Table 2. Volume of concrete

SR. NO	PLUMBING SYSTEM	VOLUMN OF CONCRETE (IN CUMEC)
1	SUNKEN PLUMBING SYSTEM	298.7
2	RAISED TOILET FLOORING	298.7
3	UNDERSLUNG PLUMBING SYSTEM	261.8

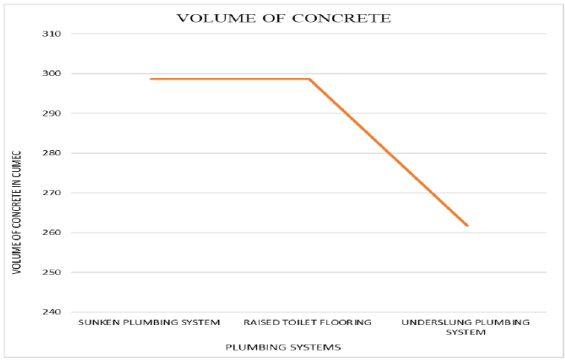

Fig.31. Volume of concrete

Steel

Table 3. Quantity of steel

DIA OF BAR	SUNKEN PLUMBING SYSTEM		RAISED TOILET FLOORING		UNDERSLUNG PLUMBING SYSTEM	
(MM)	N	KG	N	KG	N	KG
8	65194	6647.83218	65194	6647.83218	66809	6812.51373
10	15928	1624.17816	15928	1624.17816	14740	1503.0378
12	89085	9083.99745	89085	9083.99745	100463	10244.21211
16	34424	3510.21528	34424	3510.21528	13682	1395.15354
20	7263	740.60811	7263	740.60811	2448	249.62256
25	18509	1887.36273	18509	1887.36273	569	58.02093
TOTAL	**230403**	**23494.19391**	**230403**	**23494.19391**	**198711**	**20262.56067**

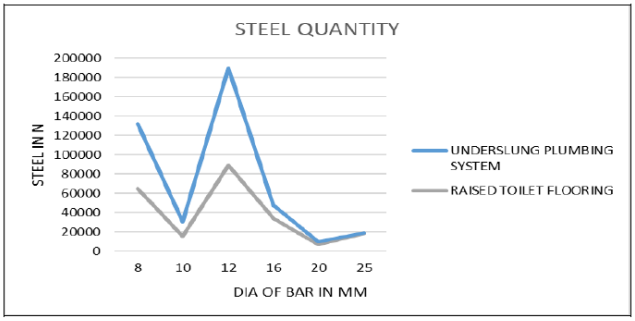

Fig.32. Quantity of steel

All three plumbing systems were subjected to RCC design using STAAD PRO, and it was discovered that the use of an underslung plumbing system resulted in a lower material requirement for construction than that of a sunken plumbing system or a raised toilet flooring system. This is because sunken and raised toilets had higher structural dead loads, and as these loads increased, so did the material requirement.

Cost comparison

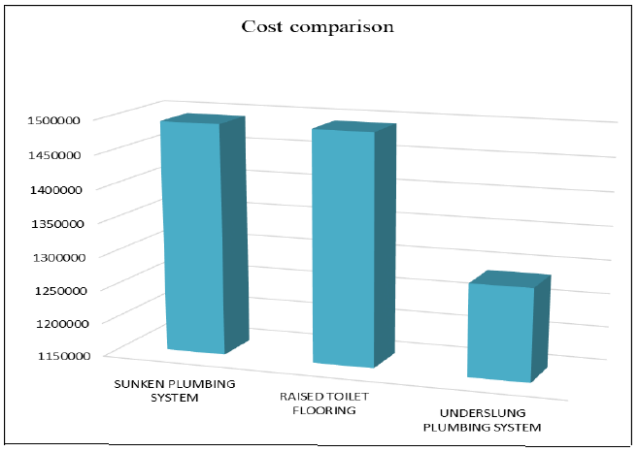

Fig.33.Cost comparison

A graphic illustration of the execution cost comparison is shown in Figure 32. The main reason why underslung plumbing systems are more cost-effective than sunken plumbing systems and raised toilet flooring is that coba filling in sunken slabs and raised portions reduces the structure's dead load, which increases the need for steel and concrete and, as a result, the sot.

It is feasible to lower the cost of coba filling in sunken and raised portions by adopting an underslung plumbing system. Underslung plumbing also requires less labour than the other two since flat slabs are simpler to construct than sunken slabs, and if sunken slabs are present, shuttering and bar binding also demand skilled labour, which raises the cost of an execution.

6. Conclusion

Separator leaks can be prevented by utilising high-quality materials and performing an efficient installation. They can also be caused by improper installation, traps in the trap, or poor material quality. Maintaining the inspection room requires taking care of its maintenance. Despite the fact that valves are actually pipes, they control the flow of material by partially or completely opening or closing a variety of channels. Leaks, overflow, backflow, and other problems might result from using valves continuously. The toilet presents the biggest plumbing and drainage issue since it has multiple fittings and one of them will break down when the toilet is being used. Is the toilet blocked; are there leaky water faucets, rotten-smelling toilets, or other fundamental services that we need to use every day. From the aforementioned investigations, it can be inferred that pipeline issues pose a serious threat to both building occupants and building longevity. The issue has emerged for a number of causes that are being looked at, and it should be minimised through careful inquiry and operation. Water pipes can be less problematic if they are constructed using high-quality materials and installed correctly.

• To prevent physical interferences with other systems like HVAC, fire, electrical, and structural or architectural aspects, it is important to use an efficient plumbing system.
• By performing various load calculations and taking into account various plumbing systems, we can create a structure cost-effective.
• By choosing a plumbing system that works well, we can shorten the design process and lower the execution costs.
• By adopting an underslung plumbing system, we can build toilets that have no sunk areas and a raised portion.
• The raised toilet floor and sunken plumbing system that result from coba filling enhance the structure's dead load.
• Raised toilet floors and sunken toilet plumbing require more concrete and steel than underslung plumbing systems.
• Plumbing that works well extends the life of structures.
• Plumbing catastrophes are decreased by effective plumbing systems.
• When compared to the other two methods, an underslung plumbing system optimises building costs.

7. Future Scope

• However, the development of technology, innovation, and construction methods will determine the scope of submerged slabs in the future. Currently, sunken slabs are utilised in building projects to increase the amount of floor space without raising the building's height and to make better use of the underground space.
• Sunken slabs could be improved in the future to incorporate cutting-edge materials, clever technology, and renewable energy sources to improve sustainability.Their use might also be expanded to constrained-space metropolitan regions or to structures that demand great security.
• People with impairments or mobility challenges have improved access thanks to raised toilet floors and underslung plumbing systems. These systems will be more in demand as the population will continue to age.
• By decreasing tripping hazards and lowering the chance of water damage from leaking pipes, systems can increase safety in bathrooms.
• Raised toilet flooring can make better use of the limited floor area while underslung plumbing systems can assist conserve space in smaller bathrooms by eliminating the need for standard plumbing fittings.
• Underslung plumbing systems can hide unsightly plumbing equipment, while raised toilet flooring can improve the aesthetic of a bathroom by hiding pipes and giving it a seamless, modern appearance.
• By saving water and cutting waste, sustainability in both underslung and sunken systems can be developed to be more environmentally friendly.
• Overall, as more people place a higher priority on accessibility, safety, and space-saving features, aesthetics, sustainability raised toilet flooring and underslung plumbing systems are likely to grow more popular in the future.

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