ANALYSIS OF TREMIE TECHNIQUE IN CONCRETING OF BOTTOM PLUG OF WELLS

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ABSTRACT:

"Tremie Technology" for pouring of concrete under water depends on the area of the dredge hole. Concept of the technology varies based on the concrete flow character vis-à-vis shape and size of the hole, where concrete is to be poured.

Conventional "Tremie Technology", applied in cast-in-situ bored piles, is pouring of concrete under water through tremie pipe from bottom to top of the dredge hole in a continuous process. Upward flow of concrete is very important in conventional tremie technology.

In case of concreting in well bottom plug, the "Tremie Technology" applied is not exactly similar to the conventional method. Due to large diameter of well, upward flow of concrete does not occur from bottom to top of the dredge hole. Concrete, during well bottom plug, spills down over the old concrete. First poured concrete does not come up.

The technical analysis of the tremie technology in well bottom plug and flow character of the concrete during bottom plug operation in wells have been discussed in the paper in comparison with the conventional tremie technology, applied in cast-in-situ bored piles.

1. INTRODUCTION:

The basic concept of this paper is "Technical analysis of Tremie Technique in Well Bottom Plug Concrete", comparing the conventional "Tremie Technology", applied in cast-in-situ bored piles. The tremie pipe concept adopted in well bottom plug is different from the tremie pipe concept, adopted in bored piles.

Diametre of well is quite large than that of pile. In large diameter dredged hole, during application of tremie pipe technology, concepts and methods of 'continuity of concrete' and 'up-flow of concrete' widely differs from the conventional concept of tremie pipe technique, as adopted in cast-in-situ bored piles.

Prior to 1983, bottom plug concrete under water in wells was being executed by 'Skip Box' system only. Since 1983 to 1995, both 'Tremie Pipe' and 'Skip Box' methods were being adopted for concreting of well bottom plug. After 1995, adoption of the 'Tremie Pipe' method was made compulsory in well bottom plug concrete.

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During concreting under water for well bottom plug with 'skip box' system, controlling of concrete quality could not be ensured totally due to certain technical hazards. To overcome these hazards and to improve the plug concrete quality, 'tremie pipe technology' in well bottom plug was adopted.

2. TECHNICAL HAZARDS FOR CONCRETE IN WELL BOTTOM PLUG WITH SKIP BOX SYSTEM & CONSEQUENT ADOPTION OF TREMIE TECHNOLOGY TO OVERCOME THE HAZARDS:

The analysis is based on the well bottom plug concrete considering as under water concrete, where wells are neither in artesian condition nor in dry condition. For such under water concrete inside the well, adopting 'skip box' system, the basic technical hazards identified and analysis thereof with suitable solution is as under:

2.1 Technical hazards with skip box system:

- During pour of concrete in wells under water, cement of the green concrete gets washed owing to turbulence generated in water and time gaps between the stages of pours of concrete. Earlier "Skip Box" system was being adopted for pouring of concrete under water. This skip boxes were having the system of both bottom & top opening. On pouring the concrete in the box, the bottom and top of the box were being closed and on reaching at the bottom required level inside water, the bottom of the box was being opened mechanically, operating from the top. In such system, wash of cement of concrete after every pour could not be avoided. Increasing percentage of cement in concrete could be the solution of strengthening the weak joints between the concrete layers, but owing to constant turbulence, generated in water due to stage pour of concrete and movement of skip box in water, controlling of concrete quality became difficult.

- Proper flow of concrete at required levels under water is also another vital aspect for well bottom plug. Concrete is required to flow smoothly over the total space of the sump and the space inside the well curb upto the end of cutting edge. While skip box was used for pouring of bottom plug concrete, it was being dropped at all possible locations in a manner to cover up all the areas at the bottom of the well. But by this system the skip boxes could not reach the corners, close to the cutting edge. Flow of concrete to the desired locations occurred only by normal gravity flow of the concrete, owing to high slump, overcoming the buoyancy effect on it. Unless the flow of concrete is controlled under pressure, integrity of the concrete under water is difficult to ensure.

2.2 Adoption of tremie technology to minimize the hazards:

- Washing of cement from green concrete, under water, can be avoided or minimized during bottom plug, if concrete is not poured in stages from top. Hence concrete is required to be poured from the bottom and in a continuous uninterrupted process. This process is implemented through "Tremie Technique".

- To ensure the flow of concrete at sump bottom level and subsequently integrity of concrete in well bottom plug, “Tremie Technique” is applied to pour concrete, by which the concrete gets additional pressure owing to the height of the tremie pipe in addition to the normal gravitational force at bottom level. Ensuring proper control of high slump and workability is also another important factor for right flow of concrete to all edges.

Now, before further analysing the ‘tremie technology’, adopted in well bottom plug concrete, a brief on ‘Conventional Tremie Technology’ concept is submitted.

3. BASIC CONCEPT OF CONVENTIONAL TREMIE TECHNOLOGY, APPLIED IN A CONFINED DREDGE HOLE:

a. Pour of concrete under water through tremie pipe shall be in a continuous process.

b. Pour of concrete shall be from bottom to top of the dredge hole. This upward flow of concrete shall carry the initial contaminated or partially washed / weak concrete, if any, above the required top level.

4. TECHNICAL ANALYSIS OF TREMIE TECHNIQUE IN WELL BOTTOM PLUG CONCRETE, COMPARING WITH THE CONVENTIONAL TREMIE TECHNOLOGY, APPLIED IN BORED PILES.

4.1 Continuity of concrete:

(i) Cast-in-situ bored piles :

In case of cast-in-situ bored piles, generally concrete is poured into tremie pipe through tremie hopper in batches. The discharged volume of concrete from tremie pipe bottom in one go fills up the total volume of sump below the tremie pipe with a spill up height substantially above the tremie bottom level, to resist the water pressure above it. Thus entry of water in tremie pipe is prevented and continuity of concrete is maintained.

(ii) Well bottom plug :

In case of well bottom plug, the bottom area being large, stage pouring of concrete in tremie hopper can not prevent entry of water inside the tremie pipe, due to non-raising of initial concrete height above tremie bottom level to neutralize the water pressure in the dredge hole. This aspect has been clarified in details supported by calculations under Para 5**.** To maintain the continuity of concrete, the concept of concrete feeding into the tremie hopper in stages has to be avoided and concrete has to be poured into the hopper in an absolute continuous manner, preferably using a concrete pump. Feeding of concrete must be continuous till the pressure equilibrium condition is attained at tremie bottom level.

4.2 Flow of concrete from bottom to top:

(i) Cast-in-situ bored piles :

In cast-in-situ bored piles, the concrete coming out of the tremie bottom under pressure, remains within the well confined influenced zone. Thus the confined concrete within the dredged hole flows upward, i.e. from bottom to top**.** A continuous upward movement in the concrete remains**.** Old concrete moves up by the upward pressure of new concrete, coming out of the tremie bottom.

(ii) Well bottom plug :

In case of tremie pipe concrete in well bottom plug, total concrete coming out of the tremie bottom gets more spread in comparison with bored pile. Concrete flow from bottom to top does not occur owing to the large area of the well. The detailed occurrence of flow of concrete during bottom plug operation in well is analyzed hereinafter. Besides this, smooth and upward flow of concrete in well also get restricted due to inclined surface of the well curb.

4.2.1 Occurrence of flow of concrete during well bottom plug operation:

The base horizontal area of the well bottom sump can approximately be split in the following zones, based on tremie concrete pressure and flow, developed on discharge from tremie pipe bottom. The well has been considered circular, having depth not less than 15 metres. The concrete has been assumed to be manufactured with 20 mm and down graded stone, having slump of 150 mm to maximum 200 mm. Use of admixtures is preferred for better workability.

1.	Central zone	Area covered by approximately 2 m radius from well centre.
2.	Outer ring area, beyond central zone	Outer periphery of this zone is demarcated with a radius of approximately 4 m from centre of the well and inner periphery by about 2 m radius from the same centre.

In wells of radius more than 4 metres, the 'tremie technique' may not function with a single tremie set. Our analysis, hereinafter, is limited to use of single tremie set, where circular well diameter (OD) is limited to 8 metres and depth of well is more or equal to 15 metres.

a.	In central zone of approximately 4 m diameter.	After initial spreading of the concrete in total area at the well bottom and reaching above the tremie pipe bottom level, new concrete pushes up the old concrete covering the area of maximum 4 m dia. Flow-up force will gradually reduce from centre to the periphery and as a result a heap of concrete like 'cone' will be created centrally around the tremie pipe. The said cone collapses gradually while concrete height increases or tremie pipe is jerked / lifted. Subsequently, in case of well diameter is more than 4 metre, concrete spreads over the outer ring area, i.e., beyond 4 m dia zone. Thus old concrete does not remain in seriatim from top**.** Refer (**Fig.1).**

b. In outer ring area beyond central zone — The old concrete in this outer ring area, beyond 4 m dia central zone, does not flow up significantly, as the upward pressure, generated centrally, does not influence this zone considerably. So, the old concrete is not being flowed up in seriatim**;** new concrete is ever accumulated over the old concrete spilling down from the central heap/cone of concrete. To ensure flow of concrete to cutting edge and to all end surfaces, high slump and workability of concrete is very important. Refer (**Fig. 1).**

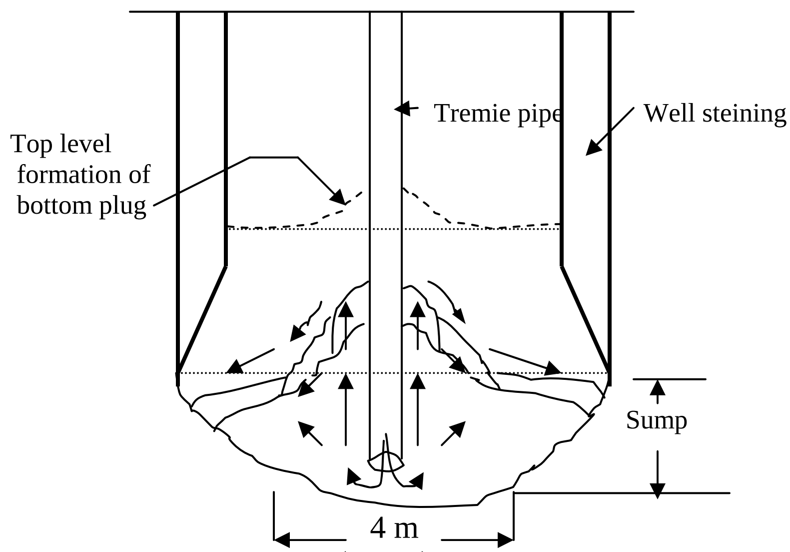


Fig. 1

Hence, like cast in situ bored piles, the old concrete is not being flowed up in seriatim in case of well bottom plug, and new concrete is ever accumulated on the top of old concrete during bottom plug operation with tremie technique.

4.3 Addition of extra cement in tremie concrete :

(i) Cast-in-situ bored piles :

In tremie concrete of bored piles no extra cement is added. Clause 6.3.3 of IS:2911 (Part I / Sec 2) clarifies the same.

(ii) Well bottom plug :

In well bottom plug concrete, new concrete is accumulated on old concrete. Thus top surface of each layer of concrete gets washed with water and partially becomes weak in strength. So, integrity of concrete is not ensured. This is not desirable from safety point of view. To overcome this problem and to strengthen the joints of concrete layers, to the extent possible, 10% extra cement is added to the concrete.

4.4 Time of concrete pouring operation while tremie technique is adopted.

(i) Cast-in-situ bored piles :

In all cast-in-situ bored piles, even of large diameter (limited to 2 m) piles, up-flow of old concrete is totally followed in seriatim as desired in conventional tremie technology. So the total concrete operation in such pile is required to be completed within final setting time of concrete (final setting time of concrete is generally increased, based on requirement, by using suitable admixture), as movement of initial poured concrete ends at the time of completion of the total concrete operation.

(ii) Well bottom plug :

In well bottom plug, concrete does not flow up. New concrete accumulates on old concrete. This aspect has been clarified under Para 4.2. 'Final setting time' factor of concrete will not therefore be applicable for such bottom plug concrete in wells. So, no restriction of time for total concrete operation during well bottom plug is imposed.

4.5 Final level of concrete :

(i) Cast-in-situ bored piles :

In bored pile, contaminated concrete, i.e. 1st batch concrete, which flows up to the top of pile, is allowed to be above the desired level.

(ii) Well bottom plug :

In well bottom plug, as the initial concrete does not flows up and remains at the bottom of well, no additional concrete is required. Plug concrete is not raised beyond the desired level.

At the final stage of well bottom plug concrete, it is observed that the central heap / cone of concrete remains above the desired level. The height of the central concrete cone may be minimized by jerking of the tremie pipe at the last stage of pouring concrete.

Full minimization of the cone may not be possible and the central heap of concrete may remain in position, provided the periphery concrete reaches the desired level. Top-level formation of bottom plug is shown in **Fig. 1**.

4.6 Concrete in single operation without interruption

(i) Cast-in-situ bored piles :

In cast-in-situ bored pile total concrete must be done in a single operation without any interruption, as concrete flows up in the pile.

(ii) Well bottom plug :

For well bottom plug, continuation of concrete in a single operation is must till the pressure equilibrium condition is achieved at the tremie pipe bottom level. Further concrete is also preferably to be done in continuity. Due to discontinuity of concrete or delay in operation, the tremie pipe may get choked with concrete. In any case, the tremie pipe must be well embedded into the concrete, all the time, till end of the operation and entry of water in to the tremie pipe must not occur.

5. JUSTIFICATION OF USING CONCRETE PUMP TO KEEP CONTINUITY OF CONCRETE FEEDING INTO THE TREMIE HOPPER INSTEAD OF DOING CONCRETE IN BATCHES:

Whether by increasing the concrete hopper volume and subsequently by increasing the quantity of initial load / batch of concrete, with the purpose to prevent entry of water in tremie pipe, well bottom plug can be executed in conventional tremie technique, without using the concrete pump. This can be answered based on the calculations only. This calculation widely varies based on the formation of well bottom sump. Formation of bottom sump depends on the type of soil at well founding level.

Considered sump formation for the following two cases**:**

Case **–** 1 while soil strata at founding level is clay / stiff clay, centrally stiff sump will be formed due to grabbing during sinking of the well.

Case **–** 2 while soil strata at founding level is sandy / silty sand, almost flat sump will be formed.

In case the full depth strata or the last few metre strata is sand / coarse sand, through which the well sinking is being done, due to less cohesion of the strata, resulting to less internal friction of the strata particles, the outside strata, during movement, may act as liquid in the influenced zone. The influenced zone is shown in **Fig. 2.**

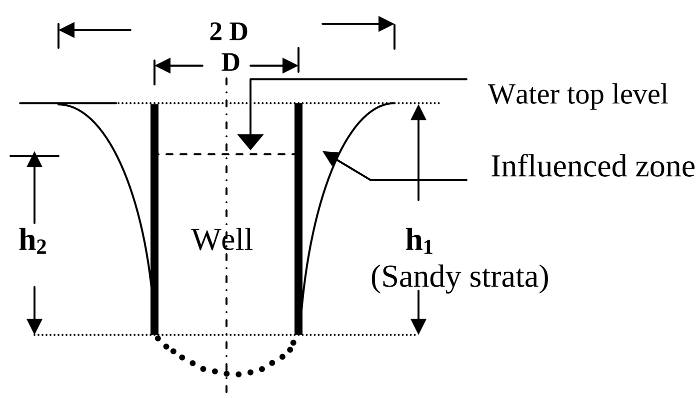


Fig. 2

While the soil strata, surrounding the well is sandy or silty sand, if $\gamma_{sand/soil}.h_1$ is more than $\gamma_{water}.h_2$, outside sand may flow inside the well. Increasing of the height of well inside water (h_2) may resist the sand blow. Entering of sand inside the well, i.e., sand blow may make the bottom sump negative. Negative sump must not be permitted. Loose sand, accumulated in the well bottom due to sand blow, must also be removed, prior to execution of bottom plug concrete.

5.1. Calculations considering stiff sump formation – Case 1.

5.1.1 Basic data & assumptions:

A set of calculations for well bottom plug, considering concrete pouring in stages without using concrete pump, (keeping the continuity of concrete), is given below for identifying the feasibility in execution. The well has been considered of 8 m outer dia and 30 m depth from ground level and bottom sump has been considered stiff at centre (as per Case - 1). Refer **Fig. 3.**

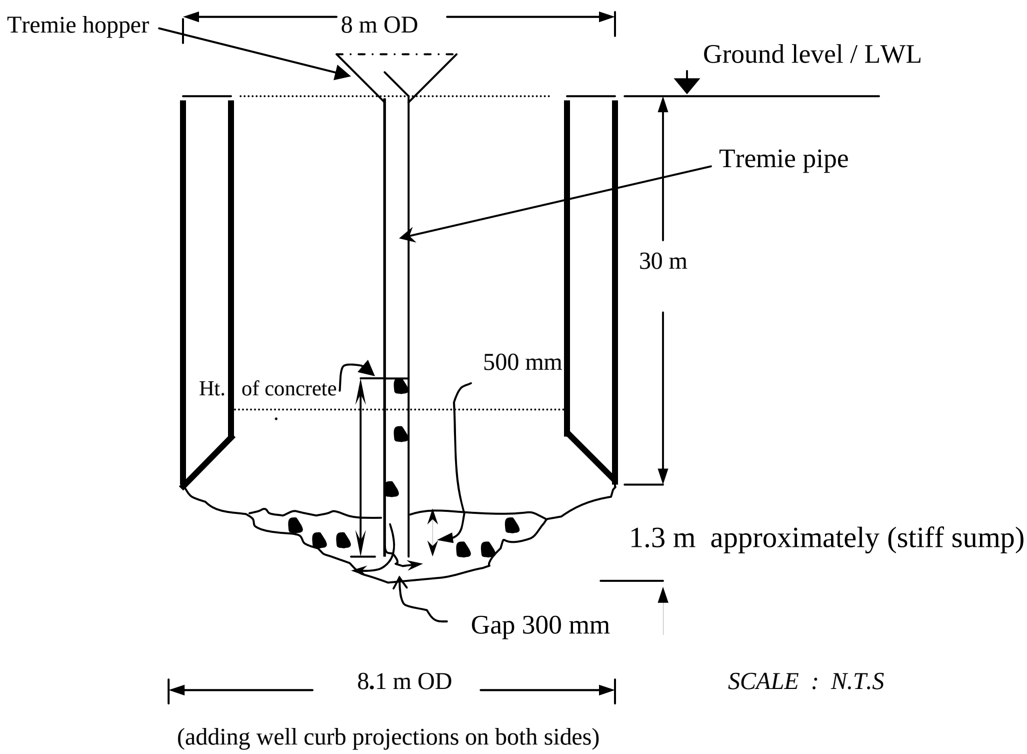


Fig. 3.

Basic data:

Well outer diameter = 8 m
Depth of well = 30 m from GL / LWL
Steining thickness = 1.4 m
Well inside diameter = 5.2 m

Assumptions:

Depth of sump = 1.3 m (stiff sump considered)
Tremie pipe height = (30 + 1.3 - 0.3) = 31 m
Standard tremie pipe diameter = 250 mm
Gap below tremie pipe = 300 mm (considered)
Volume of full tremie pipe = 1.52 m^3.
Volume of tremie hopper = 3 m^3. (considering 100% excess of tremie pipe vol.)

Weight of concrete in tremie hopper = 7.2 t

Concrete spill up outside tremie pipe (from pipe bottom level) = 500 mm (considered)

500 mm spill up of concrete from tremie bottom level has been taken as quite limiting for calculation only. In case of unavoidable turbulence in water or accidental up lift of tremie pipe, water under pressure may penetrate or leak, making passage by the side of tremie pipe surface and as a result water may enter inside the tremie pipe and break the continuity of concrete pour. If the height of the said concrete is increased for safer condition, the concrete volume will accordingly be increased and no benefit will be achieved from the feasibility point of view. Hence the calculation is based on most critical and minimum spill up height of concrete by 500 mm from tremie pipe bottom level.

5.1.2 Pressure at tremie bottom face level (considering buoyancy effect):

(after pour of first batch of concrete through tremie pipe)

Pressure developed outside the tremie pipe:

Water = 30.5 m height ; Pressure = 30.5 t/m^2.
Concrete = 0.5 m height ; Pressure = (2.4 x 0.5 – 0.5) = 0.7 t/m^2.

Total Pressure = 31.2 t/m^2.

Pressure developed inside the tremie pipe:

To maintain the pressure equilibrium condition at tremie pipe bottom face level, the concrete inside the tremie pipe should have the height
= 31.2 / 2.4 m
= 13 m

5.1.3 Required discharged quantity of concrete from tremie pipe bottom in one go i.e. per batch, to keep the continuity of concrete vis-à-vis to prevent entry of water in tremie pipe:

i) *Approximate volume of concrete accumulation in well bottom sump*
(Central sump concrete depth = 0.5 m + 0.3 m = 0.8 m)

Bottom surface of the sump is normally parabolic. For easy calculation the bottom surface of the concrete plug has been considered as a segment of a sphere.
Refer **Fig. 4.**

$$L = \frac{(5/2)^2 - (0.8)^2}{2 \times 0.8} = 3.51 \text{ m}$$

$$D = (L + 0.8) \times 2 = 8.62 \text{ m}$$

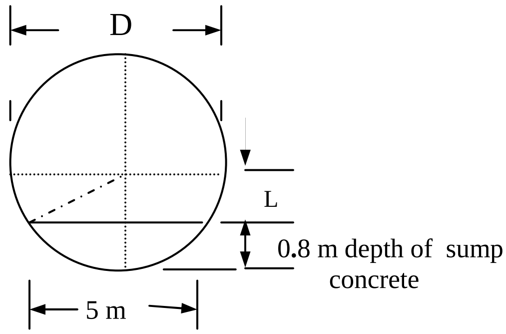


Fig. 4.

r = D/2 = 4.31 m
h = Maximum depth of concrete in sump at centre = 0.8 m
c = Maximum / Top diameter of concrete in sump = (8.1 x 0.8)/1.3 = 5 m

Volume of sump concrete = $\pi h^2 (r-h/3)$ OR $\pi h (c^2/8 + h^2/6)$
= 8.12 m^3 (accumulation of concrete in sump)

ii) *Accumulation of concrete inside the tremie pipe*

= $\pi/4 \times (0.25)^2 \times 13\ m^3$
= 0.64 m^3

So, minimum volume of concrete, required to be discharged from tremie pipe in one go **:**
= (8.12 + 0.64) m^3. = 8.76 m^3
Whereas, the volume of the tremie hopper = 3 m^3 (considered)

Volume of tremie hopper can be increased. Tremie hopper of capacity 8.76 m^3 of concrete will be of about 21 t weight, while full of concrete. Handling of the said heavy hopper may not be comfortable at site.

In such case, discharge of such large volume of concrete in one go is quite difficult, unless concrete is poured using concrete pump in a continuous manner into the tremie hopper, after opening the hopper lid.

5.2. Calculations considering flat sump formation – Case 2.

5.2.1 Basic data & assumptions:

In case the founding strata is sandy or silty sand (as in Case – 2), the sump formation will be flat and quite more concrete will be required in the first batch. Considering the sump flat and depth at centre as 500 mm, the brief calculations keeping all other factors same, are as under.

Refer **Fig. 5**.

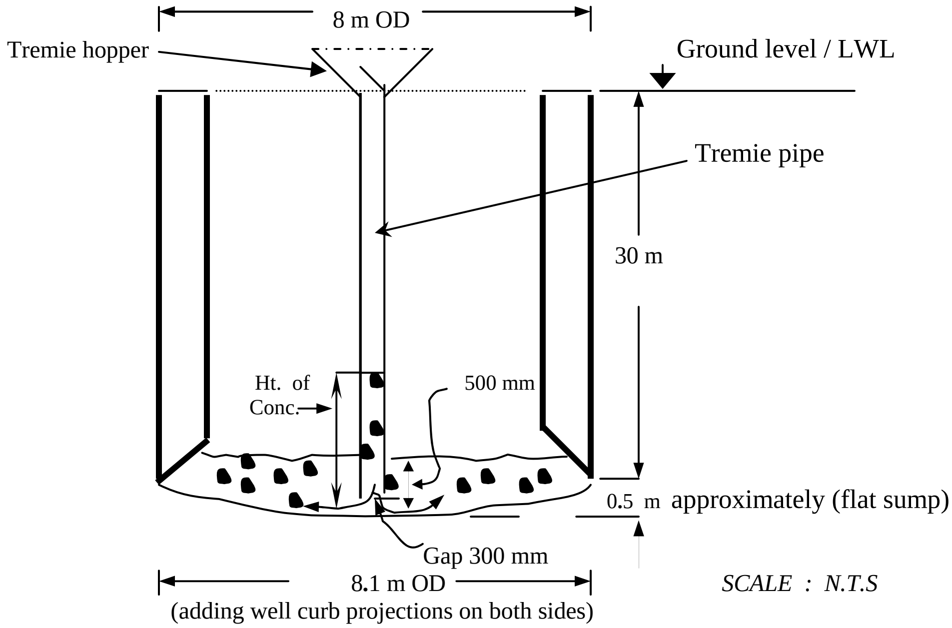


Fig. 5.

Basic data & assumptions:

Depth of sump = 0.5 m (flat sump considered)
Tremie pipe height = (30 + 0.5 - 0.3) = 30.2 m
Volume of full tremie pipe = 1.48 m^3
Volume of tremie hopper = 3 m^3
Concrete spill up outside tremie pipe (from pipe bottom level) = 500 mm.(considered)

5.2.2 Pressure at tremie bottom face level (buoyancy effect considered):
(after pour of first batch of concrete through tremie pipe)

Pressure developed outside the tremie pipe:

Water = 29.7 m height ; Pressure = 29.7 t/m^2
Conc. = 0.5 m height ; Pressure = (2.4 x 0.5 – 0.5) = 0.7 t/m^2

Total Pressure = 30.4 t/m^2

Pressure developed inside the tremie pipe:

To maintain the pressure equilibrium condition at tremie pipe bottom face level, the concrete inside the tremie pipe should have the height
= 30.4 / 2.4 m
= 12.67 m

5,2.3 Required discharged quantity of concrete from tremie pipe bottom in one go i.e. per batch, to keep the continuity of concrete vis-à-vis to prevent entry of water in tremie pipe:

i) *Approximate volume of concrete accumulation in well bottom sump* (central depth = 1 m + 0.3 m = 1.3 m)

Refer **Fig. 6**

$$L = \frac{(8.1/2)^2 - (1.3)^2}{2 \times 1.3} = 5.659 \text{ m}$$

$$D = (L + 1.3 \text{ m}) \times 2 = 13.917 \text{ m}$$

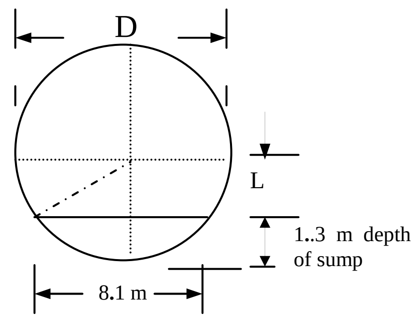


Fig.-6.

r = D/2 = 6.959 m
h = Maximum depth of sump at centre = 1.3 m
c = Maximum / top diameter of sump = 8.1 m

Volume of Sump = 34.6 m^3 (accumulation of concrete in sump)

ii) *Accumulation of concrete inside the tremie pipe*

$= \pi/4 \times (0.25)^2 \times (13.375)\ m^3$
$= 0.66\ m^3$

So, for such case, minimum volume of concrete, required to be discharged from tremie pipe in one go :

$= (34.60 + 0.66)\ m^3$
$= 35.3\ m^3$

Similarly, with this tremie hopper, discharge of such big volume of concrete in one go may not be feasible at site, unless concrete is poured in a continuous manner using concrete pump.

6. PRIMARY OBSERVATIONS PRIOR TO COMMENCE WELL BOTTOM PLUG CONCRETE:

The primary observations and actions prior to execution of bottom plug concrete are as below

6.1 Water inside the well shall be in stand still condition. There must not be any flow of water from bottom of the well due to artesian condition or whatsoever.

- This is in view not to get the concrete of bottom plug disturbed by upward flow of water during or after pouring.
- In case the well is in artesian condition, false steining on well shall be required to be raised upto the required height to overcome the water head and to make the confined water inside the well stand still.

6.2 The well shall be brought to an absolute stable condition, at least 48 hours before bottom plug operation is executed.

- No sand blow should occur after cleaning the bottom sump.
- Sinking or movement of the well should absolutely be stopped.

6.3 The water inside the well shall be kept undisturbed for minimum 24 hours to allow all sedimentations and to get the water table inside the well stable.

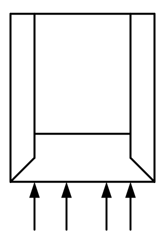
- Dewatering must not be done in the well, ready to plug, otherwise not only the water inside well, will be disturbed, even the well may get tiled or further sunk. No dewatering in other wells, in the vicinity, should also be done unless the desired well is plugged and the plug concrete attains minimum 7 days strength. For well in artesian condition, the bottom plug concrete should not be disturbed for minimum 14 days.
- If full sedimentation is not allowed before bottom plug concrete is poured, the sedimentation in water during pour of concrete may deteriorate the quality of concrete.
- Based on the depth of the well and type of soil coagulated with water, the said time of 24 hours may vary for full sedimentation.

7. IMPORTANT NOTES RELATED WITH WELL BOTTOM PLUG CONCRETE:

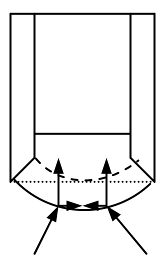
7.1 Limitation of depth of well bottom sump.

During sinking operation of the well, the central depth of the sump should preferably be limited to half of the internal diameter of the well (in any case, due to stiff clay or any other reason, the central depth of the sump must not exceed 3 m), as recommended vide Clause 2.3 of Appendix-4 of IRC:78-2000. Final central sump on termination of the well at founding level below cutting edge should preferably be around 1/6 of outer diameter of the well, limited to ¼ of outer diameter of the well. This aspect has further been clarified in details hereinafter. Bottom sump below cutting edge is not absolute necessity from design point of view, as in general, designs are based on consideration of flat bottom surface at cutting edge level, where the reaction pressures developed are considered to be axial and vertical. Consideration of parabolic arch formation between curb faces, owing to the concrete plug with sump, may economise the design, as more bottom area is available resulting to less pressure at the bottom surface. But due to uncertainty of the sump formation and unpredicted soil strata variation, normally sump is not considered in the design, except some specific cases. As well as, if concrete bulb formed in the bottom sump is very deep, the reaction pressure at the bottom concrete surface may be non-uniform, which may result to more initial settlement than what is obtained with a flat bottom surface.

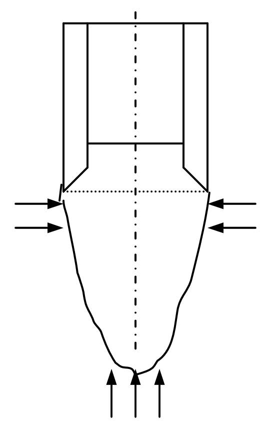
Although bottom sump formation in well, before concrete plug, is not compulsion, but as explained, the sump formation, i.e., bottom parabolic arch formation makes the well more safe from end bearing point of view, provided the bottom sump central depth is kept limited to ¼ of the outer diameter of the well. This limitation of central depth of sump is basically to ensure the formation of two-hinged flat parabolic arch in bottom plug concrete. For such type of flat parabola the distance between focus point and vertex of the parabola should be kept minimum 0.25 x OD (Outer Diameter) of the well. For more depth of sump, where the distance between focus point and vertex of the parabola is less than 0.25 x OD of the well, the parabola formation will be stiff, tending to a cone like bulb. Normally it is desirable that the focus point of the parabola (sump formation) remains on or above the cutting edge level. Calculations against four case studies are furnished below. Refer **Fig. 7.a,b,c & d.**



Flat sump
Fig. 7.a.



Parabolic sump
Fig. 7.b.



Conical bulb sump
Fig. 7.c.

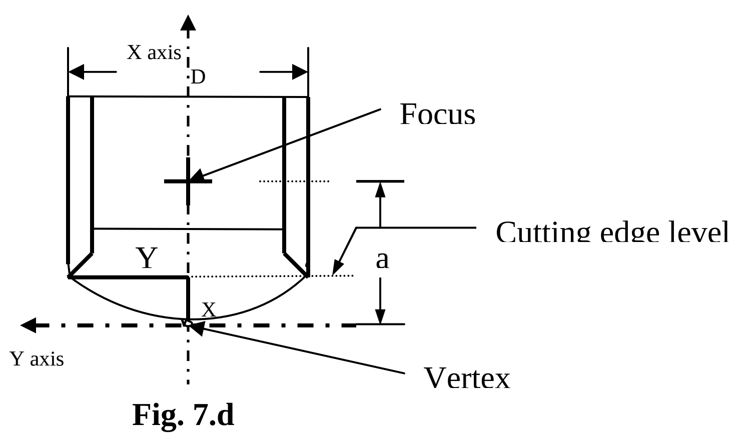


Fig. 7.d

D = Outer Diametre of well = 2 x Y
X = Central depth of Sump
a = Distance between focus to vertex.

Case-1 : a = 0.25 x D

From the formula of parabola -
Y^2 = 4 x a x X
$(D/2)^2$ = 4 x 0.25 x D x X
X = **Central depth of sump = D/4**

i.e., a = X

Focus point remains on the cutting edge level

Remarks : Sump at centre is reasonable.

Case-2: a = 0.375 x D

From the formula of parabola -
Y^2 = 4 x a x X
$(D/2)^2$ = 4 x 0.375 x D x X
X = **Central depth of sump = D/6**

i.e., a = 2.25 x X

Focus point remains above the cutting edge level

Remarks : Sump at centre is reasonable.

Case-3 : a = 0.177 x D

From the formula of parabola -
Y^2 = 4 x a x X
$(D/2)^2$ = 4 x 0.177 x D x X
X = **Central depth of sump = D/2.828**

i.e., a = 0.50 x X

Focus point remains below the cutting edge level.

Remarks : Sump at centre is high.

Case-4: a = 0.125 x D

From the formula of parabola -
Y^2 = 4 x a x X
$(D/2)^2$ = 4 x 0.125 x D x X
X **= Central depth of sump = D/2**

i.e., a = 0.25 x X

Focus point remains quite below the cutting edge level

Remarks : Sump at centre is very high.

7.2 Initial placement of tremie pipe and limitation of gap from sump bottom.

Before starting of tremie concrete, tremie pipe shall be placed into the well keeping a gap from the dredge hole bottom, so that concrete can smoothly flow down from tremie pipe through that gap. If the gap is very short, concrete may get jam at tremie bottom face. If the gap is large, concrete may get washed with water while coming out of the tremie pipe bottom due to travel of longer path. As such the said gap preferably should be minimum the diameter of the pipe and maximum twice the diameter of the pipe. In any case this gap must not be more than 600 mm.

7.3 Embedment of tremie pipe in concrete during stage lifting.

Stage lifting of the tremie pipe shall be done ensuring sufficient embedment of the tremie pipe bottom into the concrete, to prevent entry of water into the tremie pipe. Tremie pipe with hopper, while jerked to loosen the friction of concrete with the pipe surface and to clear the jammed concrete in the pipe, the pipe bottom should not come out of the concrete. Sufficient embedment of the tremie bottom into the concrete should be well ensured. The tremie pipe with hopper shall neither be lifted above concrete nor shifted in other location by dragging

8. CONCLUSION:

8.1 Tremie technique applied in well bottom plug is widely different from the conventional tremie technique, adopted in bored piles.

In normal case, for application of 'Tremie Technology' in structures, other than 'Bored Pile', comparison with the methodology and concept, adopted in bored pile, creates the confusions. Concept of the technology of tremie pipe method varies based on the shape and type of the structure. Although, the basic concept of the 'Tremie Technology' is perfectly applied in bored piles, but in other structures the technology may vary based on the structures as well as on design requirements. Design requirements for 'Pile' and 'Well Bottom Plug' are not same. In view of that, the 'Tremie Technology', applied in well bottom plug, although it is different from the technology applied in bored pile, is suitable and satisfies the requirements, considered in design.

8.2 Modification of IRC Code:

In IRC**:**78-1983 (1^{st} rev), both **'Tremie Pipe'** and **'Skip Box'** were permitted for concrete under water in well bottom plug. Subsequently in IRC**:**78-2000, clause 708**.**8**.**2 states for well bottom plug under water " the concrete shall be placed gently by ***tremie boxes*** under still water condition "**.** Based on the analysis, hereinabove, the clause 708.8.2 of IRC**:**78-2000, requires further modification. However in view of improvement of bottom plug concrete quality and execution point of view, the MoRT&H specifications have been revised stipulating the only 'Tremie Pipe' method for well bottom plug**.**

REFERENCES:

1.	IRC**:**78-2000	Standard specifications and code of practice for road bridges – Sec.vii – Foundations and substructures (Second revision)
2.	IRC Paper No. 238	Consideration in the design and sinking of well foundations for bridge piers – by Mr. B. Balwant Rao and Mr. C. Muthuswamy. References: Journal of IRC Vol. XXVII–3, August, 1963 and Vol. XXVII–5, July, 1965.
3.	IRC **:** SP **:** 33	Guidelines on supplemental measures for design, detailing and durability of important bridge structures – 1989.
4.	MoRT&H – 2001	Ministry of Road Transport & Highways. Specifications for Road and Bridge Works (Fourth edition – 2001).
5.	IS : 2911 (Part I / Sec. 2)	Code of practice for design and construction of pile foundation – Concrete Piles – Bored Cast in situ Piles.

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