# Rectification of Tilt & Shift of a Well by Kentledge Method

ROHIT KUMAR DUBEY

**Abstract:**Well foundations are quite appropriate foundation for alluvial soils in rivers and creeks where max depth of scour can be quite large. In india technology of well foundation for design and construction is quite well developed, still there are situations where serious problems are encountered at site during construction of well foundations, which results in excessive tilt of well in a particular direction. In the case of excessive tilt, regular method for tilt rectification like eccentric grabbing, water jetting, strutting the well etc. might be not so effective as required. Excessive tilt occurred during sinking of well in undergoing construction of a cable stayed bridge over river ganga have been identified & explained by the author in this presentation.

Rohit Kumar Dubey is currently persuing master degree programme in civil engineering in Dr. A. P. J.Abdul Kalam Technical University, Uttar Pradesh, India. Ph. No. +91-7549326005, email id:- rohit16may@gmail.com

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## 1. INTRODUCTION:-

When the loads from the superstructure are quite high and the soil bearing stratum is not sufficient, it does not have the sufficient bearing then, we need to go for deep foundation, so well foundation is one of that type of deep foundation. It is useful in the situation where the loads have to be transferred to the soil stratum, which are deep below from the ground surface like in case of bridge foundation. Well foundation is the most commonly adopted foundation for major bridges in India. It has been used for monuments also. Taj mahal at Agra is one such example. It is also useful in foundation where uplift loads are quite high as in the case of transmission like towers. It is the uplift load which come to the foundation and they are of very heavy in magnitude. So, in that case well foundation is quite useful. In principle the construction of a well foundation for bridges is similar to the conventional wells whose main purpose was to obtain ground water centuries ago. In planthe shape of a well foundation is similar to the caisson. When the circular well becomes uneconomical to support the pier of substructure, the well foundation can take other shapes also like double-D, rectangular, octagonal etc.

Compared to the group of piles, well foundation are rigid in engineering behavior and are able to resist large forces of floating trees or bolders that may roll on the river bed. Due to the large cross-sectional area of well foundation, the bearing capacity of soil for that area is much higher. Well foundation being hollow at the centre has large section modulus with min. cross section of area which imparts stability to well foundation.

## 2. SHAPE OF THE WELL:-

The shape of the well in plan may be circular, square, rectangular, octagonal, twin-circular, twin-octagonal, twin-hexagonal or Double-D. the choice of a particular type of well is dependent mainly on base dimension of pier or abutment, the ease and cost of construction, tilt & shift during sinking and the magnitude of forces to be resisted.

Most commonly adopted section of a well is the circular one. This has the least perimeter for a given area of the base and hence is the ideal section in terms of the effort needed during sinking. Further as the distance of the

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cutting edge from the dredge hole is equal, sinking is more uniform. In the case of large oblong piers, two or three independent, circular wells place close to each other with a common well cap can be used but they have a tendency to tilt towards each other during sinking. Double-D & Dumb-bell shaped wells have advantages in terms of being a monolithic structure and having dredge holes as circular respectively.

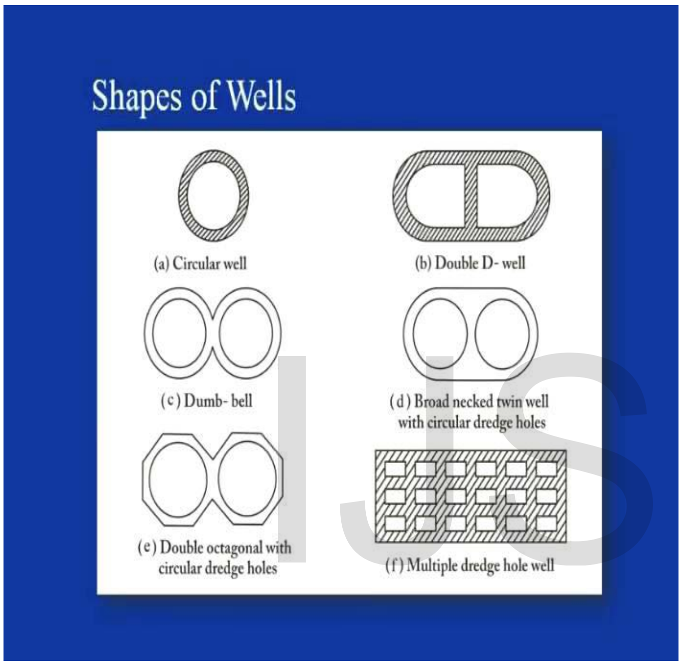


Figure 1- Shapes of Wells

## 3. COMPONENTS OF WELLS:-

**a) Well curb including cutting edge:-** The bottom portion of the well is tapered and is called the well curb. It should be strong enough to transmit the design loads to the bottom plug. The cutting edge, which is an integral part of the well curb, is usually made of mild steel plates & angles and is fabricated in 3 or 4 parts depends on the outer diameter of well. The well curb should be such that, it will offer the minimum resistance while the well is being sunk but should be strong enough to be able to transmit superimposed loads from the steining to the bottom plug.

Figure 2- Cutting Edge

Figure 3- Inner Shuttering work for Well Curb

Figure 4- Reinforcement arrangement for Well Curb

**b) Well steining:-** It is the main body of well which transfers load to the subsoil. Well steining is built of mass concrete or reinforce concrete. The well steining should be of sufficient thickness so that it can resist damage during sinking, earth pressure in condition like sand blow, stresses developed during sinking and in service condition. The steining of the well shall be built in one straight line from bottom to top such that if the well is tilted, the next lift of steining will be aligned in the direction of the tilted axis.

**c) Bottom plug:-** Once the well is reached to the required depth, then the base of the well is being plugged with the concrete and that plug is called as the bottom plug. The function of this bottom plug is to transmit the load coming from steining to the subsoil.

**d) Dredge hole:-** The well is sunk by excavating the soil from within the well. The hole formed due to the excavation of this soil is called as dredge hole. Once the well is reached at the desired or the required depth, dredge hole is filled with sand.

**e) Top plug:-** It is the concrete plug, which is covering the sand filling usually, which is constructed at the top of the well. It provides contact between well cap and sand filling and facilitate the transfer of the load from the superstructure i.e. some part of the load from the superstructure to the sand filling and then to the bottom plug.

Figure 5- Shuttering work for Well Steining

**f) Well cap:-** This is a RCC slab which is laid on top of the well steining and is usually cast monolithically with the steining, it transmits the load of superstructure to the steining.

## g) Sinking process:-

The process of taking down the well to the founding level is known as well sinking. The well shall be sunk down by excavating material uniformly from inside the dredge hole. Use of water jetting, explosives & divers may be adopted for sinking of well through difficult strata. In stagnant water and in water with velocity upto 2.0m/sec. and of depth upto about 5.0mtr., construction of island may be resorted to. In greater depth the use fo steel caissons would become unavoidable. In deeper channels and swift rivers, caissons built of steel plates suitable, strengthened by angle iron stiffeners and further strutted and tied together by MS angles may be used.

If stiff clay strata or in strata with compact sand, shingle and boulders the use of rail chisel may be required. If a very stiff clay layer is encountered during the sinking of a well, the engineer has to face a very tough and challenging situation if the well becomes stationary and does not move at all. At that time due to the action of horizontal water current force, the well may start tilting. The well becomes more vulnerable due to tilt if a strap is provided outside face of the well steining to reduce the thickness of the steining. At the initial stage if the tilt is not brought under control, the tilt goes on increasing making the situation very difficult to control. This leads to a very expansive and time consuming affair for attempting to make the well straight and vertical within practical limits. The main objective of the well sinking is to sink it straight and at the correct position. In practice, however this is not easy to achieve.

Figure 6- Sinking of Well Steining by Grabbing method

Figure 7- Sand Blow Condition around the well Steining



1.

## 2. 2. PRECAUTION TO BE TAKEN DURING WELL SINKING:-

i) **Blowing of sand:-** Great cauting is necessary when dewatering of well is done at shallow depth or when the well has not gone into the soil by atleast 1mtr. The difference in the hydraulic pressure inside and outside the well may create a passage for rush of sand from outside the well resulting in blowing of the sand. Sand blowing can endanger the safety of men working inside the well and can also cause sudden tilting of the well. Seepage of water should be carefully watched during sinking and should be checked by putting sand bags over the area where such seepage is noticed.

ii) **Quick sand condition:-** Quick sand condition may occur when fine sand or silt underlie an impervious layer of clay with a considerable hydraulic pressure below the clay layer. As soon as the layer of clay is pierced through, a steep hydraulic gradient is established across a fine sand or silt under the clay and it either starts rushing upwards or in at state of incipient motion. It has no shear strength in this state & allows the well to sink into it without offering any resistance. In most cases, the sand rises to a considerable height above the cutting edge and remains there inspite of continuous dredging. Dewatering should not be tried under any circumstance and no one should be allowed inside the well when quick sand condition develops. By keeping the water level inside the well higher, a hydraulic gradient is established in the reverse direction and the quick sand condition is not allowed to the develop. And if it does develop, there is considerable margin of safety and the well does not sink below the bed level.

iii) While sinking well in deep water, divers with their equipment should be present for emergencies.

## 4. TILT OF WELL:-

When the well is sunk by pneumatic methods, probability of major tilt is less. But when the well is sunk by grabbing method, 'tilt' is a normal phenomenon. Sinking of well is normally executed by grabbing method. While grabbing method is followed at site for sinking of well, tilt of well depends on the following criteria:-

i) **Soil characteristic:-** In case of stiff clay, tilting probability is low. But as it is difficult to sink a well through highly cohesive soil due to high friction/cohesion, relation of deep sump is the normal attitude. Due to this deep sump, well get sunk suddenly & generally as a result 'tilt' occurs.

In case of sandy soil, tilting probability remains during sinking from the very beginning. For coarser sand, making central sump is more comfortable, which helps the well to sink vertically without major tilt. In case of silty sand or silty strata, control of central sump in well becomes difficult, and as a result of which the well gets tilted.

ii) **Systematic grabbing:-** Systematic & requisite grabbing is very important to sink a well with minimum tilt.

iii) **Alignment of the well:-** It is very important to keep the alignment of the well steining straight while concreting. Zigzag alignment of steining will disturb sinking of the well and as a result the well may get tilted. Beside the above, zigzag steining alignment may cause danger to the well from design point of view.

iv) **Guage marking on well steining outer surface:-** All the guage marks should be drawn correctly or otherwise it may reflect a false/wrong tilt. Action on the basis of false/wrong tilt may even cause increase in tilt, which will create a misguidance at site.

Figure 8- Guage marking on Well Steining

## 5. METHOD OF MEASUREMENT OF TILT:-

Tilt is measured at a specific gauge mark on the well (on outer surface of the steining).

U/S & D/S denotes 'Up Stream' and 'Down Stream'

L/S and R/S denotes 'Left Side' and 'Right Side' respectively.

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Tilt of the well, as shown in Fig.1, is ED in AE length of the well

(Measured on gauge marks at AB plane)

Or, in the other way, tilt of the well is ED′ in A′E length of the well.

(considered full length of the well on the basis of A′B′ plane)

So, Tilt = 1 in (AE/ED)

OR 1 in (A′E/ED′)

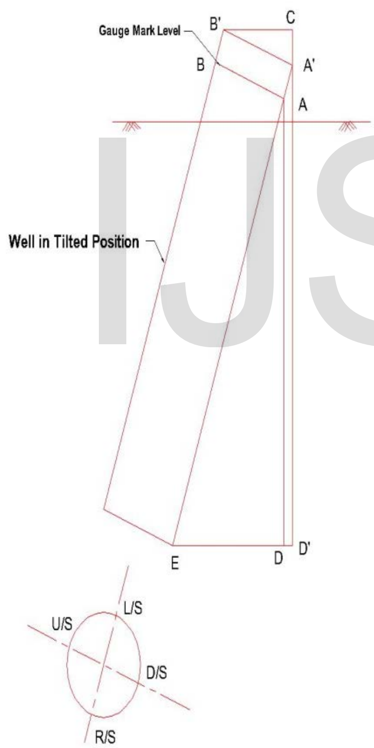


Figure 9- Sectional view along U/S-D/S

AE is well length known from gauge mark. (assumed as 25mtr.)

Considered AA′ distance = 2m

So, total well length = 25+2 = 27.00m

ED is shift at base due to tilt, for well length of 25m.

Similarly ED′ is shift at base due to tilt, for well length of 27m.

△ADE & △A′CB′ are similar.

So, AE/ED will be equivalent to A′B′/A′C.

A′B′ = Outer dia (OD) of the well

A′C = Level difference at gauge mark

So, Tilt can be measured as:

1 in A′B′/A′C (= 1 in AE/ED)

Figure 10- Tilt measurement by Auto Level

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## 6. CASE STUDY:-

Corrective measures for rectifying the tilt of well foundation for Pier P23(RHS) in a 2x2 Lane bridge with footpath across river Ganga between Sultanganj (Bhagalpur District) and Aguwani ghat (Khagaria District) including navigational span of Cable Stayed type (Connecting NH-80 & NH-31) in the state of Bihar

The 7.20mtr dia single well foundation was to be sunk to a depth of 55.20 mtr below LWL. In this, well curb is casted of 2.50 mtr. height following by individual lift of well steining of ht 2.56m & subsequent sinking of each & individual lift of steining. The curb was casted at the top of the land and sunk through the naturally filled soil strata. After the well reached the depth of 10-12mtr from ground level it met with stiff clay strata. Also the well location is sloppy towards the river side. These factors results in tilting of the well. Due to above reasons tilt of well increased from 1 in 193 at 9.0mtr sinking of well to 1 in 51 at 17.00 mtr sinking of well. As this tilt is much more than as specified in Cl. 708.5.1 of IRC:78-2000, the remedial measures have to be resorted to bring the well within the limit.

To rectify the excessive tilt, the well is loaded eccentrically against the direction of tilt & kentledge method is applied to the well during further sinking of the well. The method involves the following steps:-

**i)** Casting of steining making provision (i.e. provision of 100mm dia. hole throughout the steining by providing a PVC pipe of 100mm dia. in the steining at a height of 1.0mtr from the top surface of existing steining) for tying the steel girders with steining so that eccentric load can be placed on the top of the well.


Figure 11- Provision of PVC Pipe (Before Casting of Steining)


Figure 12- Provision of PVC Pipe (After casting of Steining)

**ii)** To reduce the outer friction, a pit to be dug as shown in the pic from existing ground level.


Figure 13- Pit around the well

**iii)** Temporary frame made wooden/Steel leg to be used as inclined support. The one end of support will be placed in inclined position, just at the point of resultant & the reaction is to be taken from concrete block casted below existing ground level.

Figure 14- Inclined Support

**iv)** The kentledge loading of adequate weight at required distance from well axis is placed eccentrically on the higher side of the well either by concrete blocks or sand bags, leaving the central space for operating the clamp shell, as shown in the sketch.

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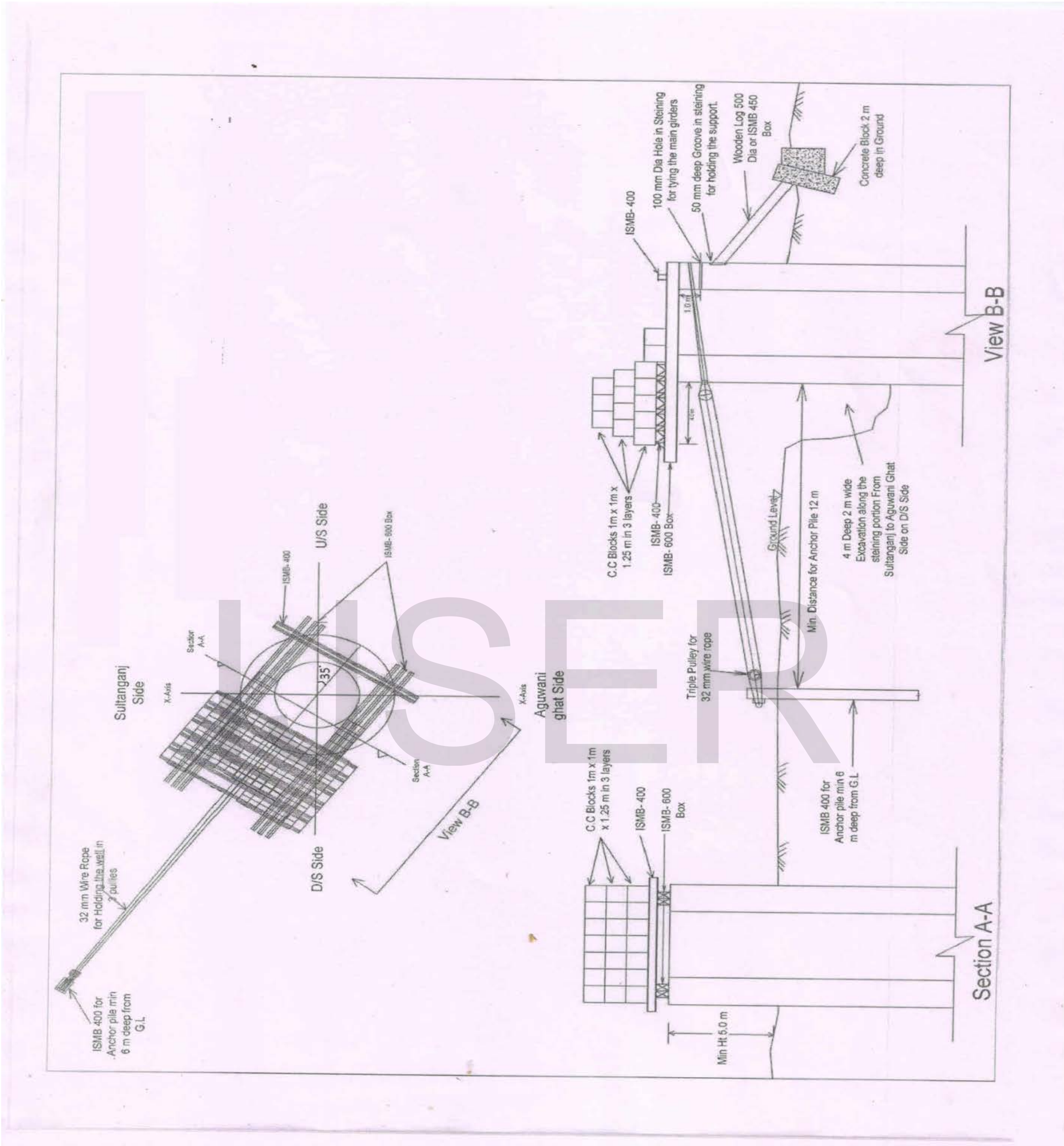


Figure 15- Loading arrangement for Kentledge method

**v)** Well is to be sunk by regulating the excavation properly and grabbing mostly on the higher side of the well.

**vi)** The well steining is tied with multiple loop by wire rope (mostly 32mm dia) and anchored using chain pulley on the higher side, as the sinking continues and the pulley is tightened in order to not to allow the well to tilt further.

Figure 16- Fixing of Steel Girder for load placement


Figure 17- Anchoring of Steel Girders with Steining by Wire rope

Figure 18- Kentledge Load Placement on Steel Girders

Tilt along X-X Axis = 115mm

Tilt along X-X Axis = 81mm

Resultant = √(1152 +812) = 140.66mm, i.e. 140.66/7200 = 1 in 51

Calculation of additional moment due to tilt:-

Total weight of well = ∏/4 [(7.2)2 – (3.94)2]*17.86*2.5 = 1273 MT

Weight above water level = (1273/17.86)*8.3 = 596 MT

Weight below water level = 1273-596-271(buoyancy force) = 406MT

Moment due to tilt at centre at level base:-

M1 = 406x9.5/(2x51) = 38 MT

M1 = 596x13.68/(51) = 160 MT

Total = M1 + M2

= 198 MT

So, to counter balance the moment due to tilt, 100 MT load is sufficient and to be placed at 2.0mt eccentricity.

## 7. CONCLUSION:-

On this paper a list of difficult situations, which bridge engineers normally encounter during sinking of well foundations, is presented. In some case the author himself devised some solutions to some perennial problems, which have been described here. The problems like the formation of hump inside the dredge hole of a well foundation or well cracking due to sand blow, or in a still clay layer well becoming stationary and not sinking down are quite common situations. Due to these situations, well starts tilting in most of the cases. Due to which tilt rectification is required to keep the structure in safe condition from structural point of view. In this paper, various methods for tilt rectification is elaborated. It may be noted that rectification of tilt of a well is more effective, only when the well is in dynamic condition. In static condition rectification may take long time or even it may not be rectified. In view of the same, well in its final stage , when balance sinking is considerably less, rectification of tilt may be very difficult,

## 8. REFERENCES:-

**1.** Dhrubajyoti Bhattacharya, "Method for evaluation of Tilt and Shift of a well" Paper published in Vol. 41 No.7. Indian Highways, Indian Road Congress.

**2.** Ch. 11, Well foundation of "Bridge Engineering" by S Ponnuswamy, Second Edition, Mc Graw Hill Education.

**3.** Gauranga Prasad Saha, The sinking of well foundations in Difficult Situations.

**4.** Vijay Kumar. "Foundation of Bridges on River Ganga in India"

**5.** "Essential of Bridge Engineering" by D. Johnson Victor, Sixth Edition.

**6.** Well Foundation, lecture by Dr. Priti Maheshwari, National Programme on Technology Enhanced Learing.