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No. NH-11052/1/87-NHIII DI *Dated the 9th March, 1987*

To,

All Chief Engineers of States and Union Territories dealing with roads

Subject : Installation of settlement plates and heave stakes for monitoring high embankment performance

In addition to special attention required for the design of high embankment, there is also a need for monitoring its behaviour and performance, during and after construction. For cases with marginal factor

of safety and/or with inadequate investigation data, this is considered to be a must. In most other cases also, a systematic observation and recording of data may be found to be most rewarding.

2. Though various sophisticated devices have been manufactured for monitoring ateral and vertical movements and pore pressures in the embankment, two very simple devices in vogue which can be easily installed and monitored by the field staff are settlement plates and heave stakes. Instructions to install these devices and recording observations had been circulated as Annexure 'K' & 'L' with this Ministry's letter No. NH-VI-50(21)/79 dated 25.1.1980. In order to encourage installation of heave stakes and settlement plates in more and more cases of high embankments these instructions have now been rewritten in specification form. These instructions on settlement plates and heave stakes together with drawing are enclosed. If some simple precautions are taken and procedures outlined in the enclosed instructions are carefully followed, it may be possible to avert in time serious adverse situations and with the help of timely remedial measures to avoid costly failures in the long run.

3. The enclosed instructions are by no means comprehensive and your comments on the procedures outlined therein or addition modification suggested in the light of your experience in actual use of these devices in the past are welcome. It shall be highly appreciated if the feed-back information specially for interesting cases describing the observations recorded and how these have helped in interpretation of actual behaviour of the high embankment during the construction and adoption of stabilising measures in time, is forwarded to the Ministry.

Encl. of letter No. NH-11052/1/87-NHIII DI dated the 9th March, 1987

SETTLEMENT PLATES

SPECIFICATION PROCEDURE FOR INSTALLATION AND RECORDING OF OBSERVATIONS

1. **Specifications**

Settlement plates shall consist of steel plate, flange, pipes and plug when fully installed as per Fig. 1. The thickness of each component and material shall be such that there is no deformation during installation or the period of settlement observation.

2. **Installation**

The plate supporting a flange one to which a section of pipe 1.5 m long is attached will be installed first. As the fill is built up additional section will be coupled to the pipe. The elevation of the top of each section will be determined as soon as it is installed and just before the next section is added.

3. **Spacing & Location**

For recording the maximum settlement under the embankment the settlement plate (Fig. 1) should be installed along the centre line of the embankment. Where raising/widening of an existing embankment is involved, the settlement plates may be placed at the toe of the existing embankment. The spacing between settlement plates shall not exceed 60 m. Settlement plates shall be provided in stretches where embankment height is more than 6 m and at locations as decided by Engineer-in-charge.

4. **Taking Readings**

Taking the readings consists of recording the RL of the top of the pipe with reference to a secured bench mark located away from the zone of influence of the embankment. During construction, readings should be taken at initial installation and at weekly intervals thereafter or every time an extension piece is added to the riser pipe. After the construction is over, readings may be taken at monthly intervals thereafter till the incremental settlement has been rendered negligible. In case, a fast rate of settlement is expected as in poor ground, the frequency of the settlement observations may be regulated that the increment of settlement observations does not exceed 20 cm. The observation may be recorded as per proforma given in Table-I.

5. **Precaution**

The settlement plate should be carefully installed on a level patch of a ground so that the verticality of the riser pipe is ensured. Some care is necessary to ensure that the riser pipe is not disturbed by construction machinery. For this purpose, an area of 2m × 2m to 3m × 3m around the riser pipe can be isolated with temporary light fencing or removable barriers (e.g. empty drums). Operation of the construction machinery beyond 2 to 3 m of the riser pipe should not, in general distribute the settlement plate. It will be advisable to protect the pipe by temporarily slicing over it (without touching) a steel pipe of bigger diametre during construction work of pavement around the area. The soil in the area around the riser pipe should be compacted by using light tempers. It should be possible to devise practical working procedures in these regards at each individual site after a little of working experience. Any unexpected or sudden change in the rate of settlement should be promptly investigated to ascertain if there is any disturbance with the settlement plate or otherwise if the stability of the embankment is affected.

Table-1 Foundation Settlement Readings

Project _____ _____ B.M. Reference
Location _____ Chainage Reference
Division _____

Settlement Plate No.	Location: Ch. on CL	Location: Offset if any from CL	Design ht. of embankment above CL at location of settlement	Date of Observation	R.L. on top of riser pipe	Length of riser pipe (including thickness of base plate)	RL of base plate (Cl.6 -Col. 7)	Settlement/ heave Of base plate since last readings	Total Settlement or heave of base plate recorded so far	Current ht. of embankment above G.L.	Remarks	Initials of Observer
1	2	3	4	5	6	7	8	9	10	11	12	13

+ = settlement
− = heave

HEAVE STAKES

SPECIFICATION, PROCEDURE FOR INSTALLATION AND RECORDING OBSERVATIONS

1. Specification

Heave stakes shall consist of 7.5 cm × 7.5 cm × 100 cm seasoned timber peg installed in 40 cm × 40 cm × 50 cm. PCC block with the top of concrete block at ground level as shown in Fig. 2. A nail shall be driven at the top of the peg to serve as reference point. The material shall be such that it does not deform during observation period.

2. Location and spacing

Two rows of heave stakes at offset distances of 2m and 5m from the average toe line of embankment (or of the stabilising berm, where one is provided) shall be laid out along straight lines ranged with the help of a theodolite and the ends of the straight lines should be defined by permanent reference pillars located away from the one of influence of the embankment. The longitudinal spacing between the heave stakes shall be 10 m. The layout of heave stakes shall be as per Fig. 2(C) for striaght alignment and Fig. 2(D) for curved alignment

3. Taking Readings

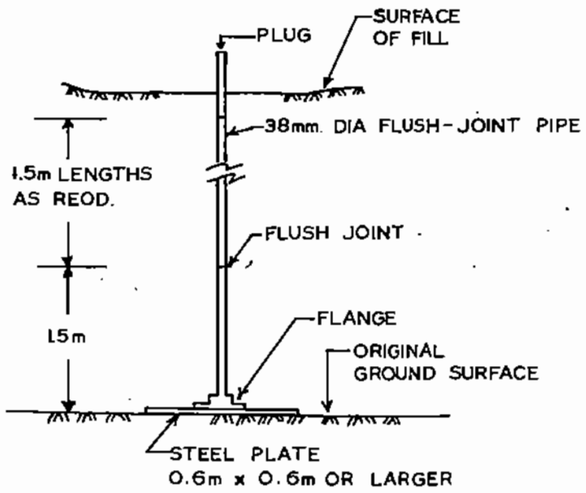
Taking readings consists of recording the lateral shift and changes in the RL of the toe of heave stakes with reference to its initial position. This requires three types of observations. Firstly the theodolite should be positioned to range the reference straight line whose ends are already defined and the offsets, if any, from this straight lines of the top of heave stakes shall be recorded. Secondly inclination of the heave stakes should be observed using plumb bob or any other simple device (for small inclination, the tangent value may be taken to be equal to the angular value of the inclination). Thirdly RL's of the tops of the heave stakes should be calculated. In case any change is noticed in the longitudinal spacing between the heave stakes, the same should also be recorded. Any apparent damage to heave stakes or distrubance of their position should be noted. The readings shall be taken in proforma given in Table 2.

Table-2 Heave stake Readings

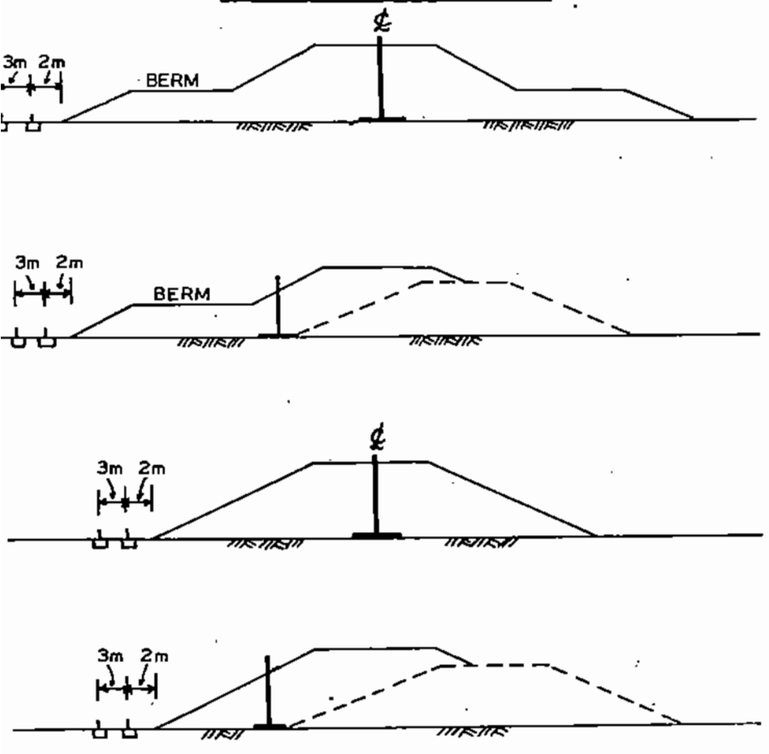
Project _____ B.M. Reference _____
Location _____ Chainage Reference _____
Division _____

Heave Stake No.	Location: Ch. on CL of Embankment	Location: Offset from CL embankment (mention U/S or D/S)	Date of observation	Offset to top of heave -take from the theodolite ranged ref. line + = towards embankment − = away from the embankment	Inclination of heave stakes with ref. to the vertical + = towards embankment; − = away from embankment	R.L. of the top of heave stake	Current height of embankment over GL at the position of heave stake	Remarks	Signature of observer

A. SETTELMENT PLATE

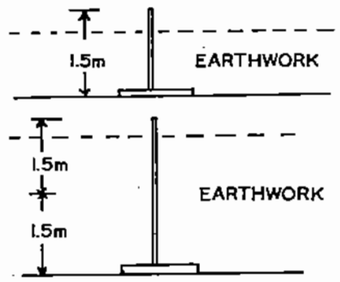


B. TYPICAL LOCATIONS OF SETTLEMENTS PLATE AND HEAVE STAKES



FOR LONGITUDINAL SPACING REFER TO NOTE 2

C. ADDING RISER PIPE DURING CONSTRUCTION.



⊥ SETTLEMENT PLATE(FIG.A)

⊥ HEAVE STAKE (FIG.2)

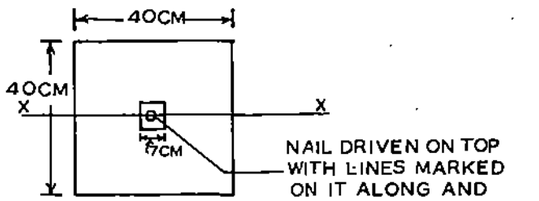
— NEW EMBANKMENT.

---- EXISTING EMBANKMENT

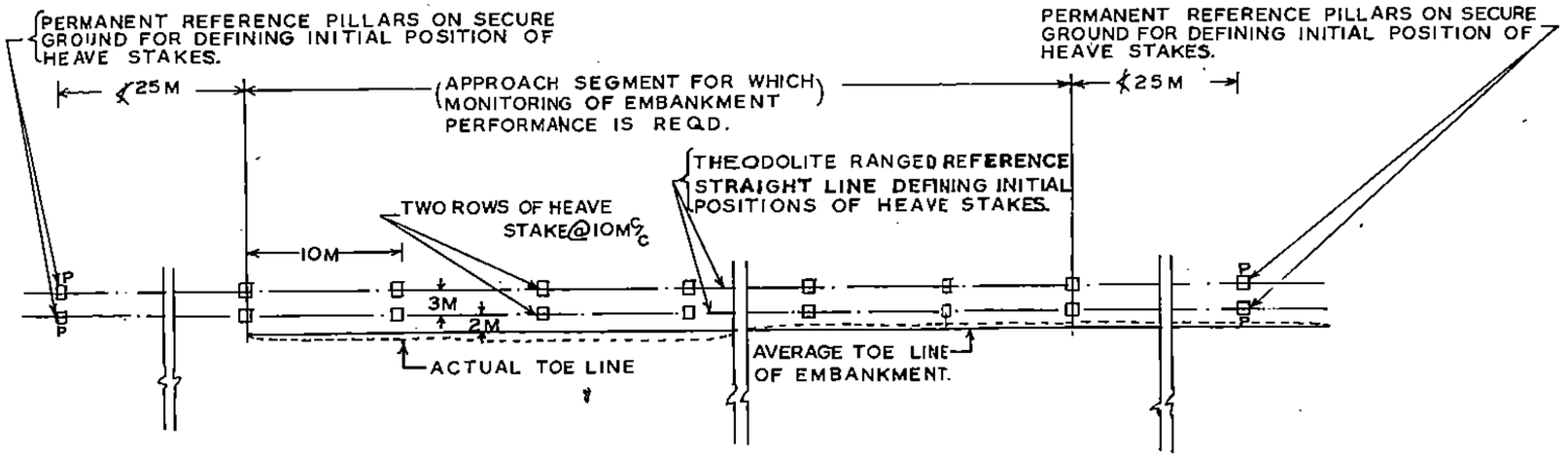
NOTES

1. SETTLEMENT PLATES SHALL BE INSTALLED IN STRETCHES WHERE DIFFERENCE BETWEEN TOE LEVEL AND ROAD LEVEL IS MORE THAN 6m.
2. ONE SETTLEMENT PLATE SHALL BE INSTALLED AT EACH CROSS SECTION AT THE MAXIMUM AT 60m INTERVAL AT CENTRE LINE WHERE NO RAISING IS INVOLVED AND AT TOE OF EXISTING EMBANKMENT WHERE RAISING IS INVOLVED AS SHOWN IN FIGURE 1 B.
3. THE THICKNESS OF EACH COMPONENT OF SETTLEMENT PLATE AND THE MATERIAL SHALL BE SUCH THAT IT DOES NOT DEFORM
4. THE PLATE SUPPORTING A FLANGE TO WHICH A SECTION OF PIPE 1.5m LONG IS ATTACHED WILL BE INSTALLED FIRST ON LEVELLED GROUND. AS THE FILL IS BUILT UP ADDITIONAL SECTIONS OF PIPE (RISER PIPE) WILL BE COUPLED. THE RISER PIPE SHALL PROJECT SUFFICIENTLY ABOVE EARTHWORK.
5. SOIL IN AREA 3m x 3m AROUND RISER PIPE SHALL BE COMPACTED BY LIGHT COMPACTION EQUIPMENTS WHICH DO NOT CAUSE ANY DISTURBANCE TO SETTLEMENT PLATES.
6. THE ELEVATION OF EACH SECTION OF RISER PIPE SHALL BE DETERMINED AS SOON AS IT IS INSTALLED AND JUST BEFORE NEXT SECTION IS ADDED AND AT WEEKLY INTERVAL DURING CONSTRUCTION FROM THIS READING SETTLEMENT OF THE BASE WILL BE CALCULATED.
7. ANY UNEXPECTED OR SUDDEN CHANGE IN SETTLEMENT RATE SHOULD BE PROMPTY INVESTIGATED TO ASCERTAIN IF THERE IS ANY EXTERNAL DISTURBANCE TO THE PLATE OR THE STABILITY IS IN DANGER. IF LATTER BE THE CASE THE CONSTRUCTION SHOULD BE HALTED AND MATTER REPORTED TO ENGINEER-IN-CHARGE.

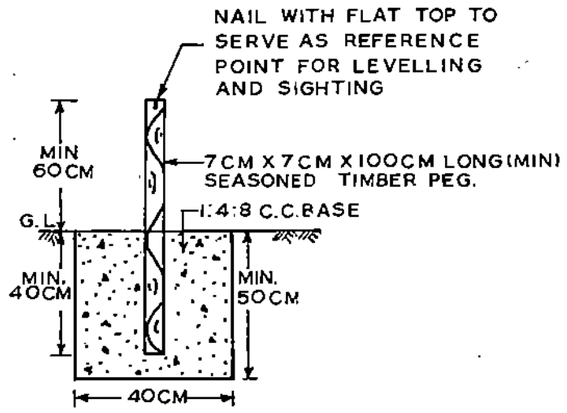
FIG. 1 – INSTALLATION OF SETTLEMENT PLATES



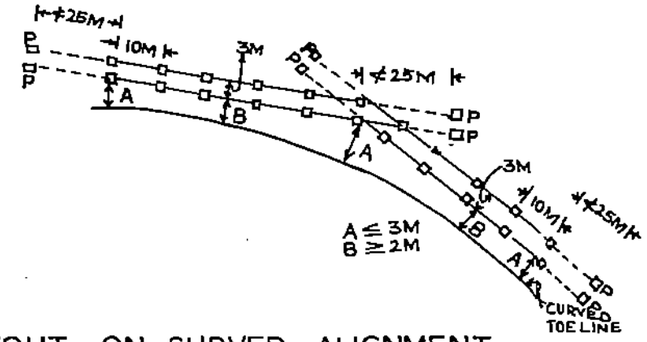
(A) PLAN



(C) LAYOUT ON STRAIGHT ALIGNMENT



(B) CROSS SECTION ALONG X-X



(D) LAYOUT ON CURVED ALIGNMENT

1. FOR LOCATION OF HEAVE STAKES WITH RESPECT TO CROSS SECTION REFER TO FIGURE I.
2. PERMANENT REFERENCE PILLAR FOR POSITIONING THEODOLITE SHOULD BE KEPT AWAY FROM ZONE OF INFLUENCE OF EMBANKMENT.
3. THE MATERIAL FOR HEAVE STAKE SHOULD BE SUCH THAT IT DOES NOT DEFORM.
4. LATERAL SHIFT WITH RESPECT TO THEODOLITE RANGED STRAIGHT LINE (IF ANY), INCLINATION OF PEGS AND REDUCED LEVELS OF TOP OF PEGS SHOULD BE OBSERVED ATLEAST ONCE IN 7 DAYS.
5. ANY MOVEMENT OF PEGS SHOULD BE PROMPTLY INVESTIGATED TO ASCERTAIN WHETHER IT IS DUE TO EXTERNAL DISTURBANCE OR DUE TO GROUND MOVEMENT. IF LATTER BE THE CASE THE CONSTRUCTION SHOULD BE HALTED UNTIL MOVEMENT HAS STABILISED AND MATTER REPORTED TO ENGINEER IN CHARGE.

FIG 2 - INSTALLATION OF HEAVE STAKES

4. Precautions

The soil supporting the base of the heave stakes should be reasonably firm, so as not to settle or move on its own or under the weight of the base of the heave stake. Care should be taken to ensure verticality of the heave stakes at the time of installation. The alignment of the top of the heave stakes should be made to conform striaght line using a theodolite as already mentioned, while the concrete at its base is still green, so that minor adjustments are possible. The disturbance of the heave stakes due to external causes, such as due to movements of machinery, men or animals should be guarded. Any unexpected or sudden changes in the position, inclination or level of the heave stakes should be promptly investigated to ascertain if this is due to external disturbance or due to ground movements. *In case of the latter, the construction should be suspended immediately until the movement has stabilised and the matter reported to the Engineer in charge.*