GUIDELINES
FOR
DESIGN AND CONSTRUCTION OF SMALL DIAMETER PILES FOR ROAD BRIDGES

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‘GUIDELINES FOR DESIGN AND CONSTRUCTION OF SMALL DIAMETER PILES FOR ROAD BRIDGES

INTRODUCTION

The draft “Guidelines for Design and Construction of Small Diameter Piles for Road Bridges” prepared by the Foundation, Sub-structure, Protection Works and Masonry Structures Committee (B-3). The B-3 Committee deliberated on the draft document in a series of its meeting and finalised the draft document for placing before the Bridge Specifications and Standards Committee (BSS). The BSS Committee approved the draft document in its meeting held on 13th January, 2015. The Council of IRC in its meeting held on 19th January, 2015 at Bhubaneshwar, (Odisha) appropved “Guidelines for Design and Construction of Small Diameter Piles for Road Bridges” after taking on board the comments offered by the members.

The Compositions of B-3 Committee is as given below :

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CHAPTER 1 GENERAL

1.1 Background

IRC:78 – 'Standard Specification and Code of Practice for Road Bridges' covers in Section V, the matters concerning 'Foundations and Substructure'.

IRC:78 – 2014, in 'SECTION 9 PILE FOUNDATIONS', specifies requirements of design and construction of pile foundations.

In the introductory Clauses itself it states that the construction of pile foundation requires a careful choice of piling system depending upon subsoil conditions and load characteristics of structures. The permissible limits of total and differential settlement, unsupported length of pile under scour and any other special requirements of project are also equally important criteria for adoption. Furthermore, in Clause 709.1.7 for river bridges it defines two zones, (i) River water zone, which is the length of waterway at Design Highest Flood Level and (ii) land portion outside on two sides. The minimum allowed diameters are specified as 1000 mm and 750 mm for them respectively. Only bored cast-in situ types of concrete piles are specified. The bridges on land like Viaducts and Road over bridges and, Under bridges, City flyovers etc. are covered in the second type.

1.2 Need of 'Small Diameter Piles'

However in all circumstances these specifications cannot be adopted. In some special circumstances described below, use of Small Diameter Piles, between 200 to 300 mm, becomes a preferable choice.

Following are some of the circumstances in urban areas where flyovers are to be constructed, which have restrictions requiring use of Small Diameter Piles.

i) The equipment to construct or install normal piles is of such dimensions that the minimum vertical and horizontal clearance necessary for its operation is not available. This can occur in cases of construction of flyovers along or across narrow roads of the city where minimum width of traffic lanes keot alongside construction area cannot be encroached upon. (In other words, where construction space is not adequate to mobilize heavy and large size piling equipment.)

ii) Locations where safety of other regular users (pedestrians and vehicles) cannot be assured if normal piles of larger diameters are to be installed.

iii) Where use of additional piles to augment the capacity of foundation using the normally constructed piles is required, but the arrangement of existing piles do not permit large increase in the size of the pile cap or the required extra strength is not large enough to justify use of large pile diameters.

iv) In case of rehabilitation/retrofitting of existing bridges, the headroom required for equipment installing piles of large diameters is not available.

1.3 References and Data

For design and construction of 'Small Diameter' Piles (short name: SD Piles, also called as Micro Piles or Mini Piles in International literature) with diameter of 200 mm to 300 m, cast in situ types with liner as specified in the following Sections of these Guidelines may be used for Road Bridges..

In addition to these Guidelines, British Standard BS EN 14199: 2005 'Execution of Special Geotechnical Works–Micropiles' and FHWA-SA-97-070 'Micropiles-Design and Construction Guidelines' may also be referred for more information. The Data from long established and experienced Manufacturers can be considered, if relevant to the chosen type of pile.

CHAPTER 2 DEFINITION AND COMPONENTS OF SMALL DIAMETER (SD) PILES

2.1 Definition of Small Diameter (SD) Piles

For the purpose of this Appendix, Small Diameter (SD) Piles are defined as load carrying cast-in situ concrete or grout piles reinforced with reinforcing steel or structural steel section having outer diameter between 200 mm to 300 mm inclusive of metallic/non-metallic or without casing. They are described also as Micro Piles or Mini Piles in International literature, which also include in their definition piles between 150 mm and 200 mm, which are not recommended by these Guidelines.

Because of the requirement of minimum cover to steel of 50 mm, and considering use of 4 to 6 bars of 12 mm or 20 mm in group of twos, keeping 40 mm clearance between the groups and thickness of casing, minimum diameter of such arrangement will need at least 200 mm diameter for SD pile.

2.2 Components of SD Piles

i) **Concrete, grout and steel**

Piles of 200 mm to 300 mm diameter are typically concrete or grout piles. The coarse aggregate of size 10 mm down is used for this purpose. The reinforcement consists of 4 or 6 main bars tied with helical secondary reinforcement. The bars are typically of 12 to 20 mm diameter conforming to IS:1784 or IRC:24. These concrete section and reinforcement detailing are designed as per IRC:112. Alternatively, a structural steel section (single I section or double channel or fabricated box section conforming to IRC:24 (see **Fig. 1**)- can be used as reinforcement. For detailing of composite structure using structural sections and shear connectors, guidelines of IRC:22 should be followed. Shear connectors connecting steel sections and concrete should be provided. Intermittent holes in the webs of the structural sections should also be provided for smooth flow of grout or concrete. Use of non-shrink grout is preferable.

ii) **Liners of SD piles**

The SD piles should be provided with either corrugated PVC/HDPE or plain M.S. tubes/pipes of MORTH Specification as liners for the portion of its full length in soil. The liner should penetrate from all sides in the socket of the founding strata in rock and/or intermediate geomaterial, which provides the pile its bearing capacity, up to the depth sufficient to seal the leakage of the grout in soil. The liners are not to be considered as load carrying members under any design situation (i.e. load combination).

In case of corrugated non-metallic pipes the corrugations should be of size sufficient for soil to move in the corrugations outside and cement grout inside to develop physical interlock between both inside and outside.

The M.S. liner should be made from strips of not less than 4 mm. Over this. adequate corrosion protection measures should be provided as per IRC:SP:80 to ensure that the liner is sufficiently durable to match the design life of the structure, which shall be considered as 100 years for new bridges. The life of the protection should be estimated on the conservative side. The shortfall, if any, should be made up by extra corrosion margin in the thickness, over and above the minimum thickness.

CHAPTER 3 DESIGN OF SMALL SIAMETER PILES

3.1 Pile as a Column

These piles are designed as columns in accordance with the normal codal provisions, primarily for axial loads.

Because of their small lateral dimension, SD piles possess a moment resistance of a very small order. Considering this, the designer must carefully devise a structural arrangement whereby the entire horizontal force acting at foundation level is transferred, in some manner, through another member to competent soil stratum, without passing it on to the shaft of SD piles. One of the simple means to achieve this is to mobilize direct passive pressure against the side face of the pile cap, or through cantilevered down-stand from the same. Alternatively, raker SD piles can be installed at rake of 1 horizontal to less than 8 vertical.

The SD piles are always provided in groups and are capped by a relatively very rigid capping slab or beam. Spacing in between piles shall however be governed by clause 709.1.5 of IRC:78.

3.2 Embedment of Piles

A SD pile should be always completely embedded in soil. The pile is designed as a short column. Although dimensionally the pile appears to be slender, the permissible compressive stresses need not be reduced since the pile is laterally supported throughout its length by the surrounding soil.

Use of such piles passing through soft marine clay stratum (SPT, ‘N’ value less than 4) or a similarly incompetent soil such as un-compacted fill, is not advisable unless some method is adopted to increase the strength of such soil stratum, as the pile capacity gets severely reduced due to slenderness effect in such cases and the effective slenderness cannot be reliably estimated.

Normally, SD piles are embedded in soil for length necessary for developing combined friction and bearing capacity with specified safety factor. Such piles have been used for up to about 25 m length.

3.3 Structural Design

3.3.2 *Grade of Concrete for SD Piles*

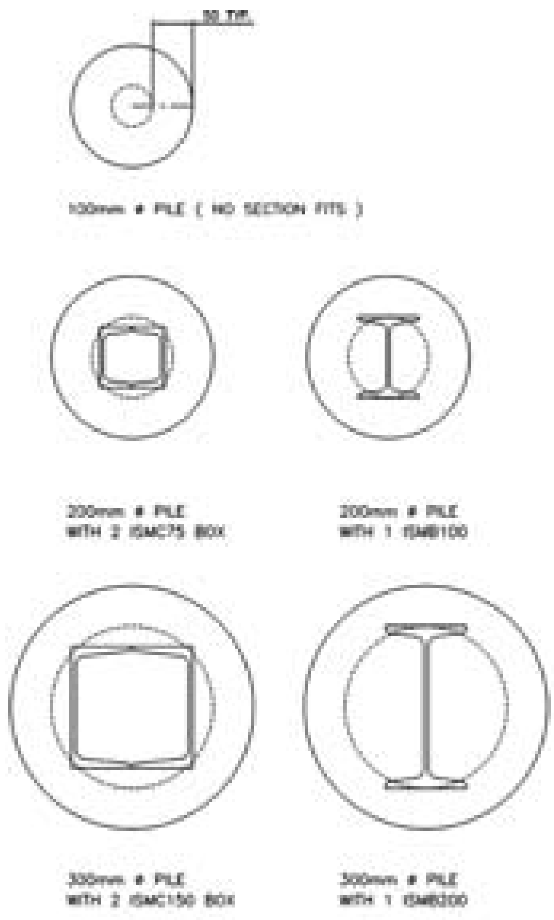
Considering the condition of exposure, the minimum grade of concrete shall be M 35 or above. The concrete shall be of Self-Compacting Concrete type. Provisions of IRC:112 should be followed for type of cement. In conditions where both sulphates and chlorides are present, use of GGBS conforming to IS: 12089 is recommended.

3.3.2 *Clear Cover to Reinforcement:*

i) Minimum clear cover to all reinforcement shall be 50 mm.

ii) For SD Piles, more than one main bar can be provided. However, the minimum clear distance between the adjacent main bars shall generally be four times the maximum size of aggregate in concrete but shall not be less than 40 mm. Main bars can be grouped as given in IRC:112, treating equivalent diameter as the diameter for the detailing purposes.

3.3.3 *SD Piles with Structural Members as Reinforcement*



The arrangement of structural steel in the pile with cover requirements is shown in the **Fig. 1**

In order to ensure proper flow of concrete and to develop bond with the same, holes should be cut in the web portion of the structural members.

Fig. 1 VSD Piles with Structural Steel Sections

CHAPTER 4 BEARING CAPACITY OF SD PILES

4.1 The bearing capacity consists of a combination of the frictional resistance along the shaft and the end bearing resistance. For piles in soils the ultimate axial load bearing capacity should be calculated as recommended in Appendix 5 (1) of IRC:78.

For piles resting in rock and intermediate geomaterials, methods recommended in Appendix 5(9) of IRC:78 should be followed. Typical calculations are enclosed.

4.2 For non-metallic corrugated lined piles frictional resistance should be the shear resistance for the type of soil through which it passes.

Where M.S. casing is used, the frictional capacity shall be computed using friction factor applicable for steel.

4.3 For verification of the capacity of pile, ultimate load test as well as routine tests as per the provisions of this Code shall be followed. The method of testing shall be as per IS: 2911 (Part 4). The typical calculations are given in the next Section for guidance.

4.4 Typical Small Diameter Pile Capacity as per IRC:78-2014 in Soils

This is a well established method. Illustrative example is, therefore, not given.

4.5 Typical Small Diameter Pile Capacity as per IRC:78-2014

In Intermediate Geo-Material and Rock

METHOD 1 –IRC:78-2014-SECTION 9-APPENDIX 5

Pile Dia. d = 250 mm, Area, A_b = 0.049 m^2

Ultimate Pile Capacity = Q_u = Ultimate End Bearing + Ultimate Side Socket Shear

= $R_e + R_{af}$

$Q_u = (K_{sp} * q_c * A_b * d_f) + (A_s * C_{us})$

$Q_{allow} = (R_e 3) + (R_{af}/6)$

Computation of R_e:

Core Recovery (CR) of Founding Strata in (2*pile depth) below pile tip = 70%

Rock Quality Designation (RQD) in founding strata, for 2 pile depth below pile tip = 30%

(CR + RQD)/2 = 50%

K_{sp} = Reduction factor based on CR and RQD = 0.3 + {(1.2-0.3) (50-30)/(100-30)} = 0.557

d_f = Depth factor = 1 + 0.4 (Socket length/dia.) = 1+ (0.4 *3/0.25) = 5.8, but limit it to 1.2

Assume UCS, q_c = 15 MPa = 1500 T/m^2 in founding depth of 2 pile depth below pile tip

Ult bearing, $R_e = K_{sp} * q_c * A_b$ * df= 0.557 * 1500 * 0.049 * 1.2 = 49.2 T , say 49T

Re allowable = 49.2/3= 16.4 T

(R_e allowable should not exceed area * 5 MPa)

Computation of R_{af}

Socket Length in founding rock strata = 3 m

For effective length of socket, deduct 0.3 m , hence effective length of socket = 3-0.3 = 2.7 m

Socket area = pi * d * l = pi * 0.25 * 2.7 = 2.12 m^2

Assume M 35 grade concrete

C_{us} = 0.225 * sqrt (q_c) = 0.225 * sqrt (15) = 0.871 MPa = 87.1 T/m^2

(C_{us} to be restricted to 3 MPa for concrete in confined condition for M 35 grade)

R_{af} = As * C_{us} = 2.12 * 87.1 = 184.8 T, say 185 T

Q_{allow} = (49.2/3) + (185/6) = 16.4 + 30.8 = 47.2 T, say 47T

METHOD 2 –IRC:78-2014-SECTION 9-APPENDIX 5

Let SPT = 100 , C_{ub} = 0.7 MPa = 70 T/m^2

N_c = 9

R_e = C_{ub} * N_c * A_b = 70 * 9 * 0.049 = 30.87 T, say 31 T

C_{us} = 70 T/m^2

Effective Socket length = 2.7 m, socket area = 2.12 m^2

R_{af} = 2.12 * 70 = 148.4 T say 148 T

Q_{all} = (31/3) + (148/6) = 10.33+ 24.66 = 34.99, say 35T

CHAPTER 5 CONSTRUCTION OF SMALL DIAMETER PILES

5.1 General

The construction of SD piles is similar to construction of bored cast in situ piles of large size. The typical construction sequence includes drilling the pile shaft to the required tip elevation, placing the steel reinforcement, placing the concrete are similar except the use of tremy. The concrete/grout shall be delivered at the bottom and pile shaft filled up from bottom upward.

5.2 Drilling

The drilling of piles can be done by either using rotary rig, percussion rig or rotary cum percussion rig as in case of bored cast in situ piles. The drilling method should avoid causing an unacceptable level of disturbance to the site and surrounding facilities. For stability of boreholes particularly in cohesionless soils and soft clays, circulation of bentonite slurry or polymer mud needs to be used to keep the differential pressure between inside and outside of pile shaft to a minimum.

5.3 Placing Steel Reinforcement

The reinforcement cage shall be prepared similarly to bored cast-in-situ piles with provision of cover blocks to achieve the required cover. The reinforcement cage shall not be provided with L bend at the tip of the pile, as it obstructs in cleaning of the boreholes of lose muck, and free flow of concrete during the placement.

The reinforcement cage may be lowered by tripod or rotary rig or supporting crane whatever is the convenient method. However, it should be ensured that reinforcement cage is lowered vertically down without scrapping the sides of the borehole.

5.4 Cleaning of Pile Tip

The pile borehole should be completely cleaned of the lose muck of the pile tip. This is normally done by bentonite or polymer mud circulation. Such cleaning is done after the lowering of reinforcement cage. In such small diameter piles, cleaning bucket cannot be used.

5.5 Concrete

It is advised to use blended cement concrete as it is more durable, sustainable and economical even in marine and highly industrialized areas. Blending may be with Fly ash or GGBS or combination of both. The amount of the mineral admixture shall be based on IS: 456. The cementatious content shall be minimum 350 kg per cum of concrete when the mix design is done.

The water content to binder ratio should be as low as possible but not more than 0.5 and slump of the concrete at the pouring point shall be 180 mm and above (self- compacting concrete is preferable but self levelling concrete is not recommended.).

5.6 Concrete Placement

Concrete placement shall be through the tremie-pipe initially resting at the bore hole tip. When tremie concreting is adopted, there is no need for adding additional 10% cement, as is done for concrete underwater. The tremie diameter should be minimum 6 times the maximum size coarse aggregate used in the concrete. It is preferable to use thread less tremie for speed and reliability. The various precautions to be taken for tremie concreting are the same as bored cast-in-situ pile. The concrete shall be poured above cut off level generally up to 300 mm and this concrete shall be removed in green stage only.