Stability of Pipeline and details of Anchor blocks

For Offshore pipeline laying

at Gulf of Kutch, Gujarat.

Client

WELSPUN (I) LTD, Gujarat

EPC Contactor

PATEL CONSTRUCTION CO.

Consultants

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CONTENTS

List of Figures

List of Tables

1. Background of the client

Welspun city is situated at Anjar town in Gujarat state is a diversified manufacturing base spread over 2500 acres land established in 2004 having more than 25000 employees. Welspun group companies harbors Home Textile-Terry Towel & Bed sheets, steel pipes & plates manufacturing units at Anjar facilities.

Welspun Indian Ltd , a group co. of Welspun, intent to lay onshore & offshore pipeline into Gulf of Kutch & awarded an EPC contract to M/s Patel Construction Company for laying onshore & offshore pipeline for treated waste water disposal into sea.

2. Introduction

Patel construction, Gandhidham, have taken up installation of an outfall pipeline near Tekra, Gandhidham. The pipeline carries treated industrial waste water. The total quantity of water is about 25 MLD discharged in 22 hrs. The pipeline diameter is envisaged to be 500mm OD. It is expected to be buried 5000mm below the prevailing sea bed. The density of effluent is 1005 kg/m3 and ambient water density if 1023 kg/m3. The following table summarizes details of pipeline parameters and wave cum current environment at site. For wave and conditions, earlier studies carried out at Gulf of Kutch by IIT Madras is used.

<u>Given Data</u>

Pipe Dia	D = 500 mm
Thckness of pipe	t =20 mm
Inner dia of pipe	d = 460 mm
Density of pipe	$\rho_p = 950$ kg/M^3
Density of water	$\rho_w = 1035$ kg/M^3
Maximum possible wave height	$H_0 = 0.8$ m
Mean wave period	T = 3.5 sec
Surface current	V = 1.2 m/sec
Safety factor	$\gamma_w = 2.5$

3. Stability of Outfall Pipeline

Stability calculation for HDPE pipelines have been performed for Effluent disposal at Gulf of Kutch, Gujarat. These pipelines span from pumping station on the landward end to the marine outfall location. The total length of outfall line is 9 km. The pipeline is to be laid below the seabed with a suitable over burden. The over burden suggested for the present pipeline is 5000mm. Normally, a over burden of 1 Diameter is the minimum required. In the present case, the project region has high currents. Hence, higher over burden may be needed. It is recommended that a over burden of 1000 mm is sufficient as the stability of pipeline is ensured by anchor blocks.

In buried pipelines, anchor blocks are needed for sinking the pipeline. However, in the present case , there is high possibility of pipeline being exposed by removal of over burden by current and wave. Hence, stability shall be provided by anchor blocks. The design shall be as per DNV RP-F109. From high water level to about 1m water depth location, the pipeline might be destabilized if not anchored properly. Hence, the stability of the same has to be critically evaluated to ensure serviceability of the pipelines all throughout its design period.

4. Forces acting upon the Pipeline

A pipeline laid at or beneath the sea bed experiences an uplift force due to buoyancy and a downward force due to gravity. In deepwater conditions the weight of water column above the pipeline also accounts for the downward force in addition to the self-weight of the pipeline, and the bed particle velocity is also negligible. In near shore conditions the risk of uplift of pipelines is very high, since the net force acting in the downward direction is lesser than that in deepwater condition due to the absence of water column. To overcome this problem, anchorage block units made of RCC will be deployed. These blocks weigh 3.493 kN and are placed at 0.8m centre to centre spacing to ensure stability.

5. Stability Calculation

Table 1: Design Specification for Anchor blocks

Depth (m)	Area of concrete Block (m^2)	Thickness of Concrete (m)	Volume of Concrete provided (m^3)	Volume of Concrete required (m^3)	Weight required		Weight Provided (kN)	Spacing
					Vertical stability (kN)	Absolute lateral Stability (kN)		
1	0.95	0.25	0.238	0.22	3.26	3.25	3.493	0.8 m C/C
2	0.95	0.25	0.238	0.17	3.26	2.53	3.493	
3	0.95	0.25	0.238	0.14	3.26	2.11	3.493	
4	0.95	0.25	0.238	0.13	3.26	1.9	3.493	
5	0.95	0.25	0.238	0.12	3.26	1.71	3.493	
6	0.95	0.25	0.238	0.11	3.26	1.54	3.493	
7	0.95	0.25	0.238	0.10	3.26	1.46	3.493	

Stability Calculation

Given

Pipe Dia	D =	0.50	m
Thickness	t =	0.02 m	
Inner dia	d =	0.460m	
Density of pipe	ρ_p =	950	kg/m^3
		9.5	kN/m^3
Density of sea water	ρ_w =	10.35	kN/m^3
Maximum possible wave height	Ho =	0.8	m
Mean wave period	T =	3.5	Se
Surface current	V =	1.2	m/sec
Saftey factor	γw =	2.5	
Depth of Water	d =	1	m
Deep water wave angle	θ0 =	40	Degree
	n0 =	0.5	

Solution

Vertical stability in water

$$\gamma_W \cdot \frac{b}{w_s + b} = \frac{\gamma_W}{s_g} \leq 1.00$$

i)Pipe buoyancy per unit length B

$$= \rho_w \cdot g \cdot \pi \cdot D^2 / 4 \ .$$

=ρw x Vol. of submerged pipe

b= 2.55 kN

ii) Weight of submerged pipe Ws = Vol. of pipe x ρ_p

Ws= 0.50 kN

I. Vertical stability in water

$$\gamma_W \cdot \frac{b}{w_s + b} = \frac{\gamma_W}{s_g} \leq 1.00$$

$$\gamma w * \frac{b}{Ws + b} \leq 1$$

Ws = Wpipe + W Anchor Block

$$\gamma w * \frac{b}{(Wb + Wc) + b} \leq 1$$

Take 1

Weight of anchor block Wc= 3.26 kN

II. Absolute lateral stability

$$\gamma_{SC} \cdot \frac{F_Y^* + \mu \cdot F_Z^*}{\mu \cdot w_s + F_R} \leq 1.0$$

and

$$\gamma_{SC} \cdot \frac{F_Z^*}{w_s} \leq 1.0$$

Horizontal Force

$$F_Y^* = r_{tot,y} \cdot \frac{1}{2} \cdot \rho_w \cdot D \cdot C_Y^* \cdot (U^* + V^*)^2$$

Vertical Force

$$F_Z^* = r_{tot,z} \cdot \frac{1}{2} \cdot \rho_w \cdot D \cdot C_Z^* \cdot (U^* + V^*)^2$$

Oscillatory velocity amplitude for single design oscillation, perpendicular to pipeline. U*

$$= \frac{\pi * H}{T} * \frac{1}{\mathrm{Sinh}\,(k * d)}$$

Wave Length calculation
Using linear wave theory,

U* = 0.36 m/sec
V* = 1.2 m/sec

Peak horizontal co. efficient C*y = 1.35 From table
C*z = 0.94

Reduction factor $r_{tot,i} = r_{perm,i} \cdot r_{pen,i} \cdot r_{tr,i}$

Penetration depth Z.p = 0.25 M 50% of Dia of Pipe
Trench depth Z.t = 1.5

Z.p/D = 0.50
Z.t/D = 2.68
r.perm = 0.9
r.pent.y = 0.3 r.pent.z = 0.5 From chart 3.5
r.tr.y = 0.7 r.tr.z = 0.65 & 3.7 DNV

r.total.y = 0.19
r.total.z = 0.29

$$F_Y^* = r_{tot,y} \cdot \frac{1}{2} \cdot \rho_w \cdot D \cdot C_Y^* \cdot (U^* + V^*)^2$$

Horizontal Force

1.79 kN

Vertical Force

$$F_Z^* = r_{tot,z} \cdot \frac{1}{2} \cdot \rho_w \cdot D \cdot C_Z^* \cdot (U^* + V^*)^2$$

1.93 kN

Absolute static stability

$$\gamma_{SC} \cdot \frac{F_Y^* + \mu \cdot F_Z^*}{\mu \cdot w_s + F_R} \leq 1.0$$

and

$$\gamma_{SC} \cdot \frac{F_Z^*}{w_s} \leq 1.0$$

Co-efficient of friction

□ □	0.2
□□□	0.8

Saftey factor of soil γ.sc = 1.4 From table 1.4 - DNV

Passive soil resistence FR=

$$\frac{F_R}{F_C} = \frac{4.1 \cdot \kappa_c}{G_C^{0.39}} \cdot \left(\frac{z_p}{D}\right)^{1.31}$$

$$G_C = \frac{s_u}{D \cdot \gamma_s} \quad \text{and} \quad \kappa_c = \frac{s_u \cdot D}{w_s - F_Z} = \frac{s_u \cdot D}{F_C}$$

VRL contact pressure	FC=		Ws-FZ	1.90
Un-drained clay shear strength	s.u =		1	
		k.c =	0.30	
Dry unit soil weight		γ.s =	18	kN/M^3
		G.c =	0.10	for clay
		FR =	2.28	0

Absolute static stability

$$\gamma_{SC} \cdot \frac{F_Y^* + \mu \cdot F_Z^*}{\mu \cdot w_s + F_R} \leq 1.0$$

and

$$\gamma_{SC} \cdot \frac{F_Z^*}{w_s} \leq 1.0$$

Take 1

Weight of anchor block Wc = 3.25 kN I

Wc = 2.14 kN II

Volume of Concrete

$$Vc = \frac{\text{Weight of Anchor block}}{(\text{Density of concrete} - \text{Density of water})}$$

Vc = 0.22 M^3

Towing Condition

i) Buoyancy force for 1 pipe b= 2.55 kN

ii) Weight of submerged pipe Ws = Vol. of pipe x pp + Weight of Concrete block

Ws= 4.06 kN

Ws > b

So provide one pipe on top of upper anchor block to enable floatation while towing.

b= 5.10 kN

Ws= 4.63 kN

Ws < b

The configuration of marine outfall pipelines and the reinforcement details for an Anchor block are shown in the Fig.1 to Fig.4 respectively.

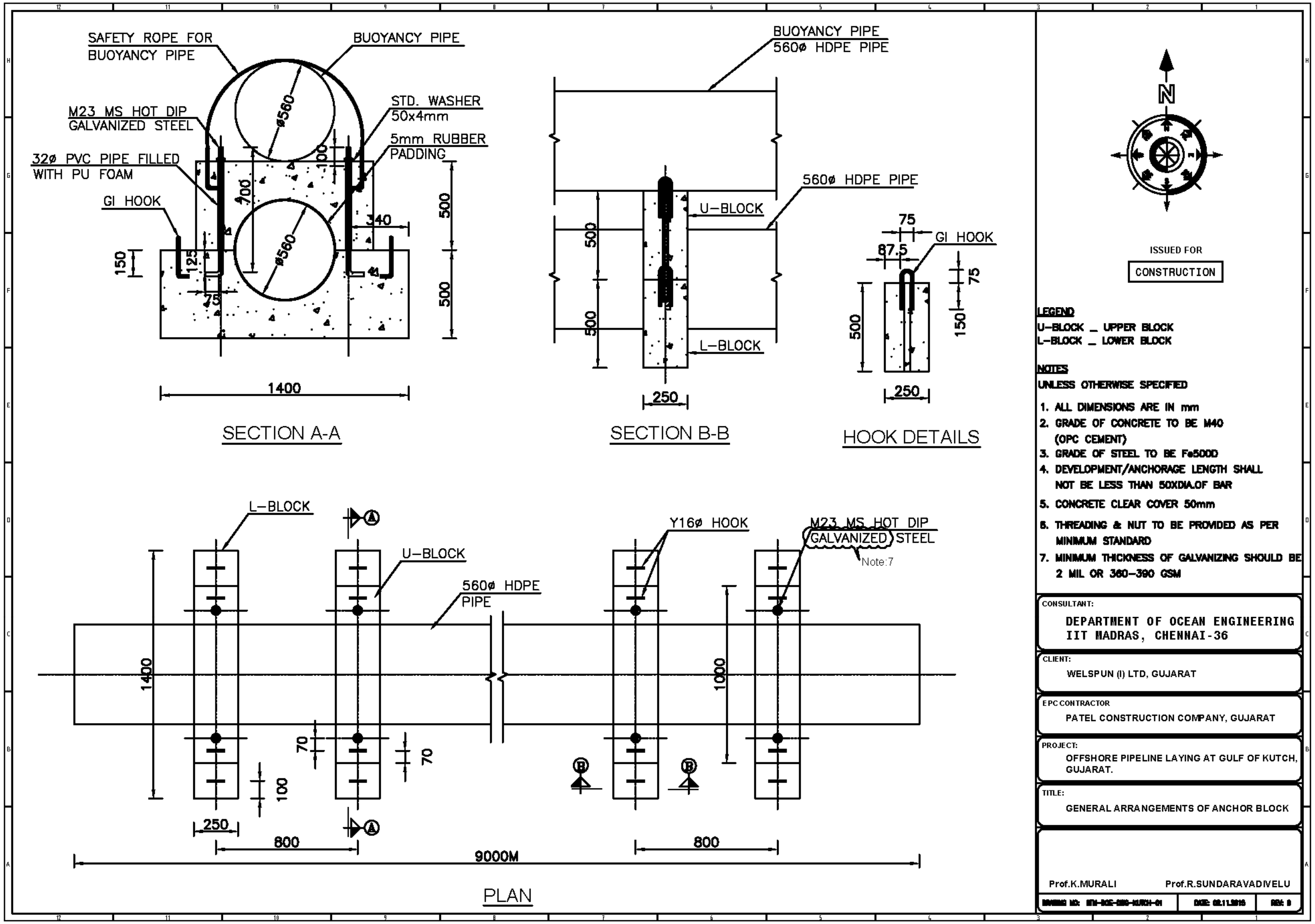

Fig 1: General Arrangements of Anchor block

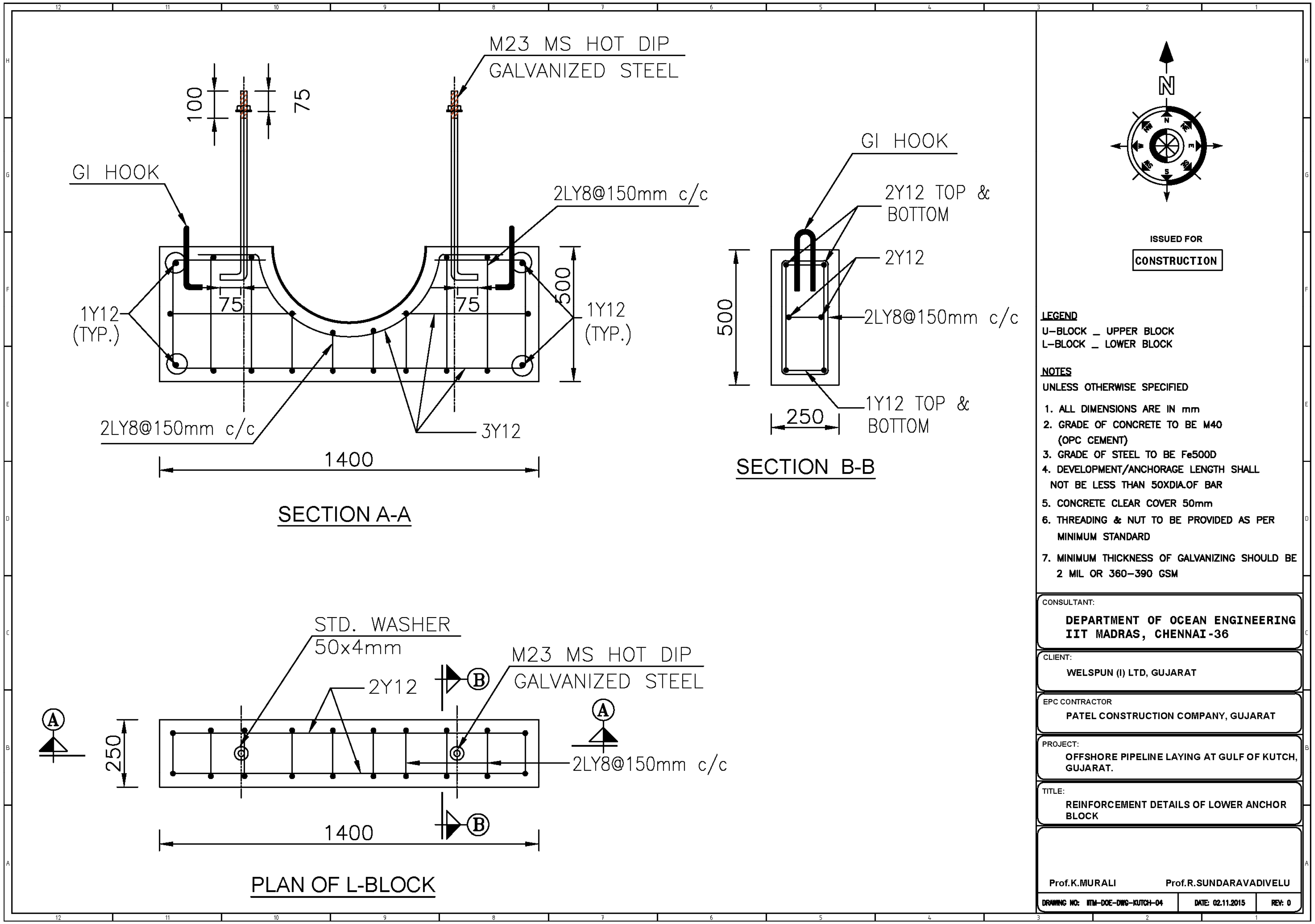

Fig 2: Reinforcement details of Lower anchor block

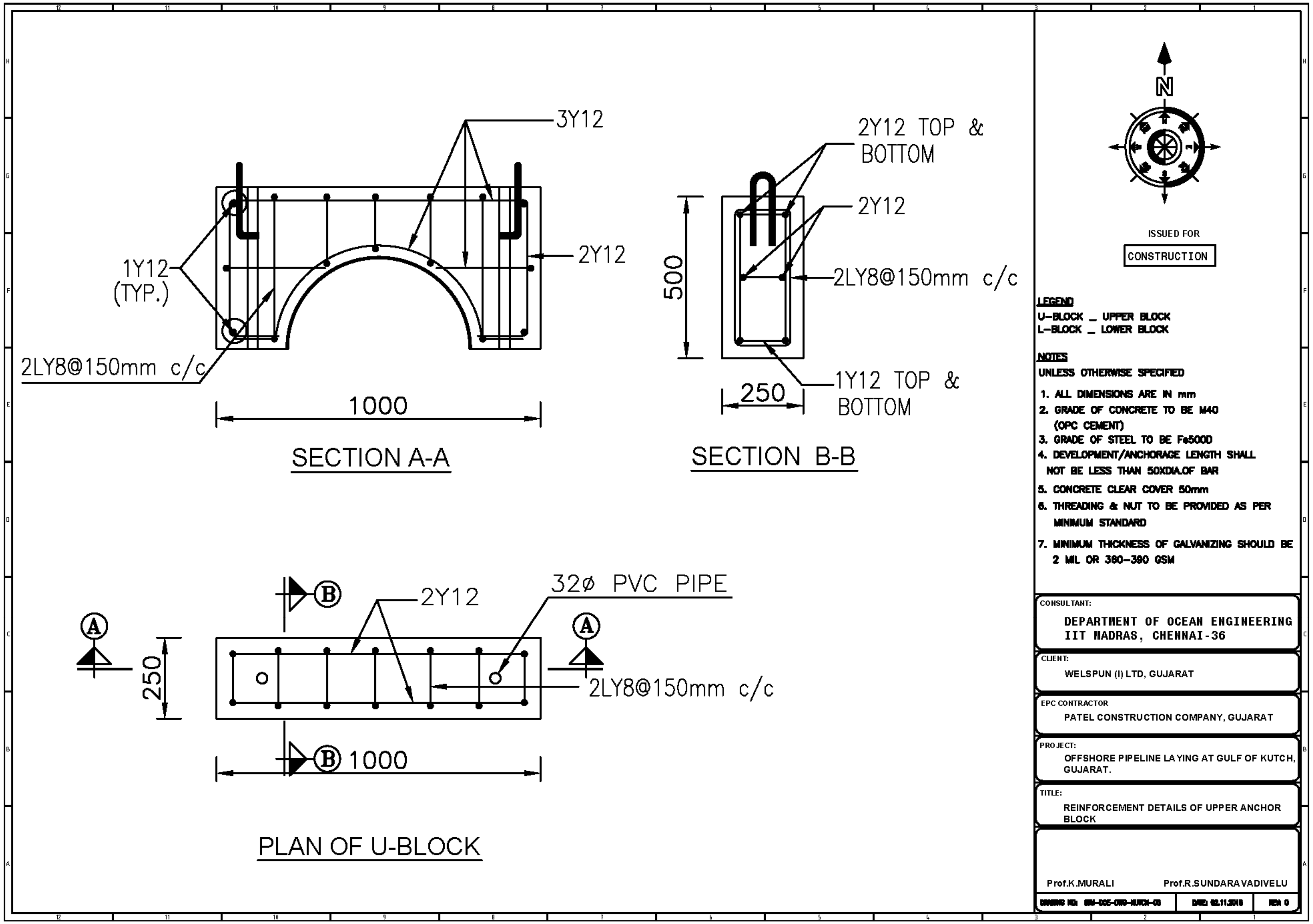

Fig 3: Reinforcement details of Upper anchor block

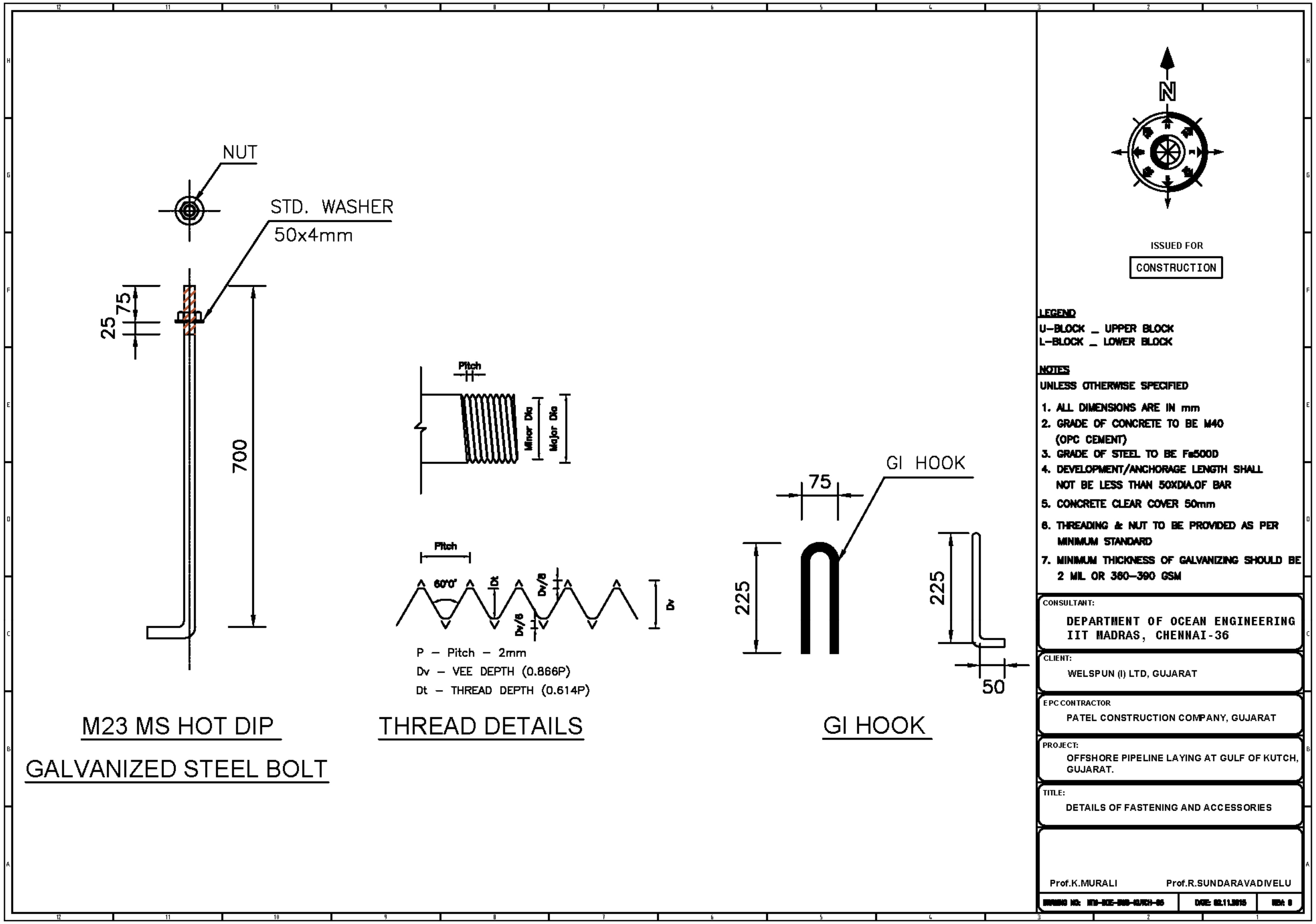

Fig 4: Details of Fastening and accessories