DESIGN CALCULATION COVER SHEET

Project	Detailed Design on Port Reactivation Project in La Union Province	**Project Code**	JC1N004
Section	**Civil**	Calc. File No.	
Sub-Section	**Quaywall**	Calc. Index No.	

Subject: **Passenger Berth**

Calculation Objective:

Rainforcement of Breasting dorphin

References, Calculation Notes and Comments

Refer todrawings **QW-02-006,QW-02-007**

Calculation based on

TECHNICAL STANDERDS AND COMMENTARIES

FOR

PORT AND HARBOUR FACILITIES IN JAPAN

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9 . Detail Design of Breasting Dolphin (Passenger Berth)

1) Examination Case

An examination case is performed about berthing and mooring condition like a basic design. Moreover, only LWL condition with bigger pile head moent examines. The examination case of calculation of reinforcing bar arrangement is shown below.

	Deadweight	Reaction Force of the Fender	Tractive Force
Berthing Condition	○	○	—
Mooring Condition	○	—	○

Moreover, calculation of reinforcing bar arrangement of each examination case examines only ultimate limit state and serviceability limit state.

2) Partial Safety Load

The partial safety factor used for this examination is shown below.

(1) Load Factor

	Ultimate limit	Serviceability limit
Deadweight	1 . 1	1 . 0
Reaction Force of the Fender	1 . 2	1 . 0
Tractive Force	1 . 2	1 . 0

(2) The other nimbers of partial safety factor

		Ultimate limit	Serviceability limit
Material factor	Concrete	1.30	1.00
(γ m)	Reinforcing bar	1.00	1.00
Structure analysis factor(γ a)		1.00	1.00
Member factor(γ b)		1.15～1.30	1.00
Structure factor(γ i)		1.20	1.00

※Member Factor

When calculating bending and axial strength : 1.15

When calculating upper limit of axial compressive strength : 1.30

When calculating shear capacity borne by concrete : 1.30

When calculating shear capacity borne by shear reinforcement : 1.15

In calculation of reinforcing bar arrangement, reaction force of the fender and Tractive Force is treated not as accidental load but as variable load. Therefore, partial safety factor of both loads sets to 1.2, and structure factor of each examination case is set to 1.2.

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3) Calculation Method of Cross-Sectional Force

The cross-sectional force of superstructure is computed using 2-dimensional framework model (simple beam). Action load is multiplied by the partial safety factor. The pile head moment uses what is computed by the basic design. (Calculation of pile head moment has the large influence of free length of pile, spring constant (grand), and all horizontal force. Therefore, pile head moment at the time of the variable load action by serviceability limit state hardly changes with the thing of ultimate limit state. Therefore, the same value as pile head moment computed by the basic design is used for pile head moment by variable load of serviceability limit state.) Moreover, the action direction of the external force, which acts on superstructure, is as follows.

Berthin Condition : the vertical direction to the face line

Mooring Condition : the vertical and parallel direction to the face line

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4) Calculation of Load

(1) Deadweight

W = 8.0×8.0×3.0×24 = 4,608.0 kN

Equivalent uniform distribution load at the time of calculating cross-sectional force as a simple beam.

w = 4,608.0 / 8.0 = 576.0 kN/m

(Ultimate limit) W = 4,608.0×1.1 = 5,068.8 kN 、w = 576.0×1.1 = 633.6 kN/m

(Serviceability limit) W = 4,608.0×1.0 = 4,608.0 kN 、w = 576.0×1.0 = 576.0 kN/m

(2) The pile head moment by reaction force of the fender (Berthing condition)

Pile 1 M = 1,078.00 kN・m

Pile 2 M = 1,170.00 kN・m

(Ultimate limit) M = 1,078.00×1.2 = 1,293.60 kN・m

(Serviceability limit) M = 1,170.00×1.2 = 1,404.00 kN・m

(3) The pile head moment by tractive force (Mooring condition)

(Action direction : the vertical direction to the face line)

Pile 1 M = 1,906.00 kN・m

Pile 2 M = 2,070.00 kN・m

(Ultimate limit) Pile 1 M = 1,906.00×1.2 = 2,287.20 kN・m

Pile 2 M = 2,070.00×1.2 = 2,484.00 kN・m

(Serviceability limit) Pile 1 M = 1,906.00×1.0 = 1,906.00 kN・m

Pile 2 M = 2,070.00×1.0 = 2,070.00 kN・m

(4) The pile head moment by tractive force (Mooring condition)

(Action direction : the parallel direction to the face line)

Pile 2 − 1 M = 2,005.50 kN・m

Pile 2 − 2 M = 2,006.00 kN・m

(Ultimate limit) Pile 2 − 1 M = 2,005.50×1.2 = 2,406.60 kN・m

Pile 2 − 2 M = 2,006.00×1.2 = 2,407.20 kN・m

(Serviceability limit) Pile 2 − 1 M = 2,005.50×1.0 = 2,005.50 kN・m

Pile 2 − 2 M = 2,006.00×1.0 = 2,006.00 kN・m

From the calculation result of load, since the load of mooring condition is larger than Berthing condition, examination of Berthing condition is excluded and only examination of mooring condition is performed.

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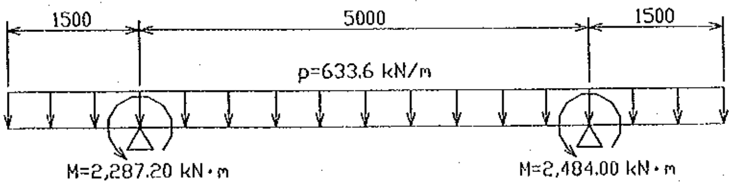
5) Calculation of the Section Force

(1) Ultimate Limit State

a) The vertical direction to the face line

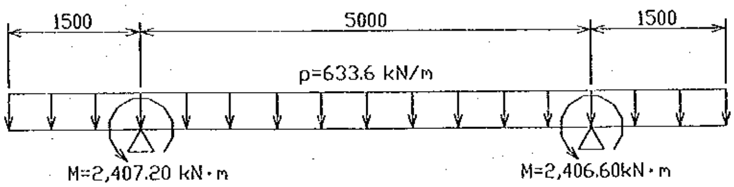


Maximum bending moment upper side M = 3,000.00 kN・m

lower side M = 2,084.16 kN・m

Maximum shearing force S = 2,538.24 kN

b) The parallel direction to the face line



Maximum bending moment upper side M = 3,120.00 kN・m

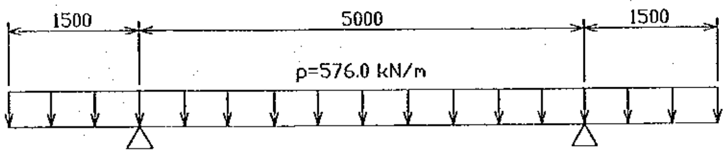
lower side M = 1,998.24 kN・m

Maximum shearing force S = 2,546.76 kN

(2) Serviceability Limit State

a) The case where permanent load is acting

The cross-sectional power by permanent load serves as the value with same the vertical direction to the face line and the parallel direction to the face line.



Maximum bending moment upper side M = 648.00 kN・m

lower side M = 1,152.00 kN・m

Maximum shearing force S = 1,440.00 kN

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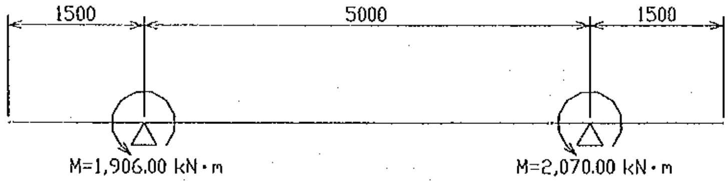
b) The case where variable load is acting

(action direction : the vertical direction to the face line)



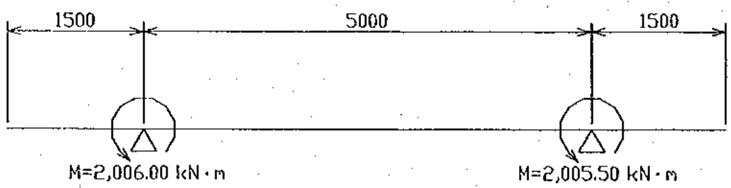
Maximum bending moment upper side M = 1,906.00 kN・m

lower side M = 2,070.00 kN・m

Maximum shearing force S = 795.00 kN

c) The case where variable load is acting

(action direction : the parallel direction to the face line)



Maximum bending moment upper side M = 2,006.00 kN・m

lower side M = 2,005.50 kN・m

Maximum shearing force S = 802.30 kN

(3) Generalization of the load in each limit state

a) Bending Moment (kN・m)

	Ultimate limit		Serviceability limit			
	upper side	lower side	Permanent load		Variable load	
			upper	lower	upper	lower
Vertical direction to the face line	3,000.00	2,084.16	648.00	1,152.00	1,906.00	2,070.00
Parallel direction to the face line	3,120.00	1,998.24	648.00	1,152.00	2,006.00	2,005.50

b) Shearing Force (kN)

	Ultimate limit	Serviceability limit	
		Permanent load	Variable load
Vertical direction to the face line	2,538.24	1,440.00	795.00
Parallel direction to the face line	2,546.76	1,440.00	802.30

6) Calculation of Reinforcing Bar Arrangement

Calculation of reinforcing bar arrangement is performed by RC section calculation program. (FORUM8 Co., Ltd)

(1) Examination of Ultimate Limit State

a) Examination of Bending Strength

The area of reinforcing bar to be used calculates it as satisfying the following conditions.

$\gamma_i \cdot M_d / M_{ud} \leqq 1.0$

- M_d ; calculated value of bending moment acting on pile in design
- M_{ud} ; design bending moment capacity、 It computes by the following formula.

$$M_{ud} = \frac{C'_c(d - y_c) + C_s(d - d')}{\gamma_b} = \{A_s f_{yd} d - A'_s f'_{yd} d' - \frac{(A_s f_{yd} - A'_s f'_{yd})^2}{1.7 f'_{cd} b}\} / \gamma_b$$

- C'_c ; The compression resultant of concrete (N) $(=0.68 \cdot f'_{cd} \cdot b \cdot x)$
- C'_s ; Compressive force of acting on a compression reinforcing bar (N) $(=A'_s \cdot f'_{yd})$
- T ; tensile force of a tensile reinforcing bar (N) $(=A_s \cdot f_{yd})$
- As ; area of reinforcing bar in tensile zone (mm^2)
- A's ; area of reinforcing bar in compressive zone (mm^2)
- d ; effective depth of a tensile reinforcing bar (mm)
- d' ; effective depth of a compressive reinforcing bar (mm)
- x ; distance of a compression end and a neutral axis (mm)
- y_c ; $=0.4 \cdot x$ (mm)
- f_{yd} ; design tensile yield strength of steel (N/mm^2) $(=f_{yk}/\gamma_{ms}=345\ N/mm^2)$
  - f_{yk} ; tensile yield strength of steel $(=345\ N/mm^2)$
  - γ_{ms} ; material factor of steel (=1.0)
- f'_{cd} ; design compressive strength of concrete (N/mm^2) $(=f'_{ck}/\gamma_{mc}=18.5\ N/mm^2)$
  - f'_{ck} ; characteristic compressive strength of concrete $(=24\ N/mm^2)$
  - γ_{mc} ; material factor of concrete (=1.3)
- γ_b ; member factor of bending members
- γ_i ; structure factor

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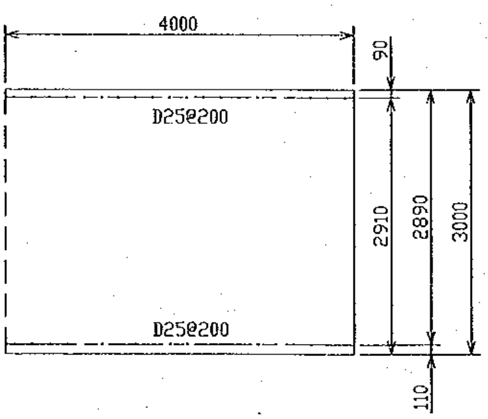
・Examination of bending moment capacity of ultimate limit state

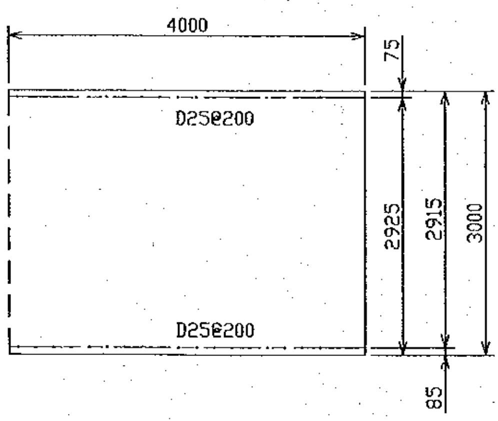
		unit	The vertical direction to the face line		The parallel direction to the face line	
			upper	lower	upper	lower
reinforcing bar (tension side)			D25	D25	D25	D25
reinforcing bar (compression side)			D25	D25	D25	D25
number of reinforcing bar (tension side)			20	20	20	20
number of reinforcing bar (compression side)			20	20	20	20
area of reinfocement (tension side)	A_s	cm^2	101.34	101.34	101.34	101.34
area of reinfocement (compression side)	A'_s	cm^2	101.34	101.34	101.34	101.34
width of member	b_w	mm	4,000	4,000	4,000	4,000
effective depth (tension side)	d	mm	2,910	2,890	2,935	2,915
effective depth (compression side)	d	mm	2,890	2,910	2,915	2,935
f_{yd}		N/mm^2	490	490	490	490
f_{cd}		N/mm^2	24	24	24	24
M_{ud}		kN·m	8,808.14	8,713.17	8,846.30	8,775.23
M_d		kN·m	3,000.00	2,084.16	3,120.00	1,998.24
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.409	0.287	0.423	0.273
Judgment			O.K	O.K	O.K	O.K

・Dimension of an examination section

The vertivcal direction to the face line



The parallel direction to the face line



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b) Examination of the Shearing Force

The steel reinforcement to be used calculates it as satisfying the following conditions.

$\gamma_I \cdot V_d / V_{yd} \leqq 1.0$

$V_{yd} = V_{cd} + V_{sd}$

V_{yd} ; design shear capacity

V_{cd} ; design shear capacity without shear reinforcement. It computes by the following formulas.

$$V_{cd} = \beta_d \cdot \beta_p \cdot \beta_n \cdot f_{vcd} \cdot b_w \cdot d / \gamma_b$$

f_{vcd} ; $0.2\times(f'_{cd})^{1/3}$

β_d ; coefficient to consider influence of effective depth on shear capacity

$\beta_d=(1000/d)^{1/4}$

β_p ; coefficient to consider influence of longitudinal reinforcement on shear capacity

$\beta_p=(100\cdot p_w)^{1/3}$

β_n ; coefficient to consider influence of axial force on shear capacity

$\beta_n=1+M_0/M_d$ $(N'_d \geqq 0)$ when $\beta_n>2$, β_n is taken as 2.0

$\beta_n=1+2M_0/M_d$ $(N'_d < 0)$ when $\beta_n<0$, β_n is taken as 0.0

N'_d ; design axial compressive force (N)

M_d ; design bending moment (N·mm)

M_0 ; decompression moment necessary to cancel the fiber stress due to axial force at the tension fiber corresponding to design moment M_d

b_w ; web width (mm)

d ; effective depth (mm)

p_w ; balanced ratio of reinforcement=$A_s/(b_w\cdot d)$

A_s ; area of reinforcing bar (mm^2)

f'_{cd} ; design compressive strength of concrete $(=18.5N/mm^2)$

γ_b ; member factor (=1.30)

V_{sd} ; design shear capacity carried by shear reinforcing steel

$$V_{sd} = \frac{A_w \cdot f_{wyd}}{S_s}(\sin\alpha_s + \cos\alpha_s)\cdot z/\gamma_b$$

A_w ; total amount of area of shear reinforcement over the interval S_s (mm^2)

f_{wyd} ; design yield strength of shear reinforcement $(=345\ N/mm^2)$

α_s ; angle between shear reinforcement and member axis

S_s ; spacing of shear reinforcement (mm)

z ; distance from compression resultant to centroid of tension steel

Generally , d/1.15

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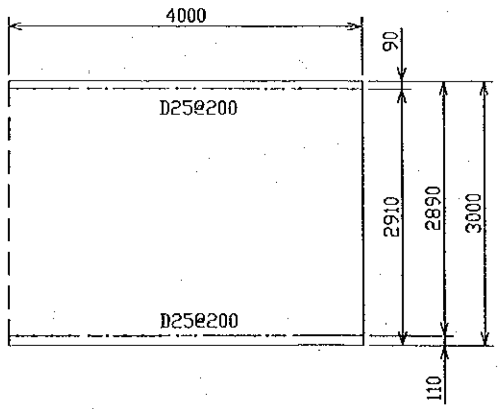
γ_b ; member factor

・Examination of shearing force capacity of ultimate limit state

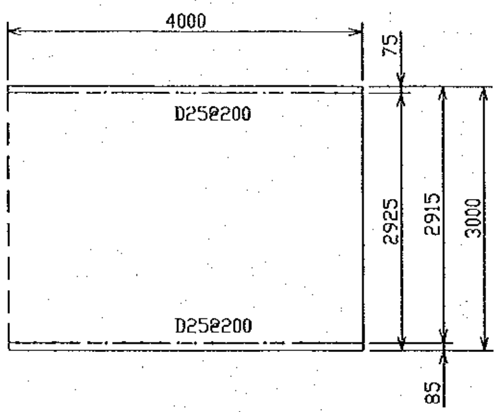
		unit	The vertical direction to the face line	The parallel direction to the face line
reinforcing bar			D25	D25
number of reinforcing bar			20	20
area of reinforcing bar	A_s	cm^2	101.34	101.34
width of member	b_w	mm	4,000	4,000
effective depth	d	mm	2,890	2,915
axial compression force	N'_d	kN	0	0
A_w	A_w	mm^2	11.460	11.460
α_s		°	90	90
s		mm	200	200
V_{cd}		kN	1,600.74	1,606.75
V_{sd}		kN	4,319.93	4,357.30
V_{yd}		kN	5,920.67	5,964.05
V_d		kN	2,538.24	2,546.76
Examination result ($\gamma_i \cdot V_d / V_{yd}$)			0.514	0.512
Judgment			O.K	O.K

・Dimension of an examination section

The vertivcal direction to the face line



The parallel direction to the face line



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(2) Examination of Serviceability Limit State

Design load is computed using the following formulas.

$S_k = k_p \times S_p + k_r \times S_r$

where

S_k : characteristic value of load for examination of the serviceability limit state

S_p : characteristic value of permanent load

S_r : characteristic value of variable load

k_p, k_r : constants to represent the effects on crake widths and the corrosion of steel by the permanent load and variable load, respectively. It may be taken that k_p is 1.0 and k_r is 0.5.

a) Examination of Flexural Cracks

Flexural crack width (w (mm)) is computed by the following formulas.

$$w = k \cdot \{4c + 0.7 (Cs - \phi)\} \cdot \left(\frac{\sigma_{se}}{Es} + \varepsilon'_{csd}\right)$$

k ; constant indicating the effect of the bonding properties of the steel material, which may usually be taken as 1.0 in the case of deformed bars.

c ; covering(mm)

Cs ; distance between centers of steel materials(mm)

ϕ ; diameter of steel materials(mm)

ε'_{csd} ; constant introduced to represent the increase of crack width caused by creep and drying shrinkage of concrete (this can be o under seaweter, and elsewhere 150×10^{-6})

σ_{se} ; increased stress on reinforcement $(=M_e/(A_s\, j\, d))$

Es ; Young's modulus of reinforcement $(=2.00 \times 10^5$ N/mm$^2)$

M_e ; bending moment

A_s ; area of reinforcing bar (mm^2)

j ; Distance between stress (mm)

d ; effective depth (mm)

Permisible crake width is computed by the following formulas.

- Permisible crake width upper side reinforcing bar w_a=0.0040 c (mm)
  lower side reinforcing bar w_a=0.0035 c (mm)

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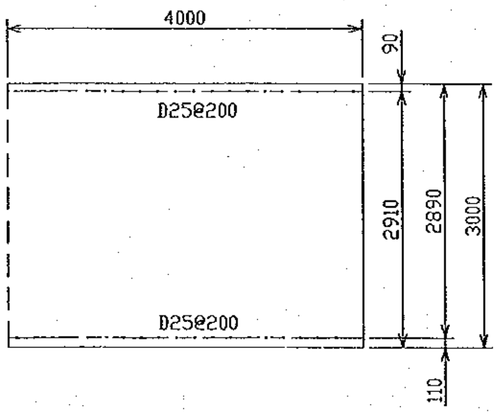
・Examination of flexural crack of serviceability limit state

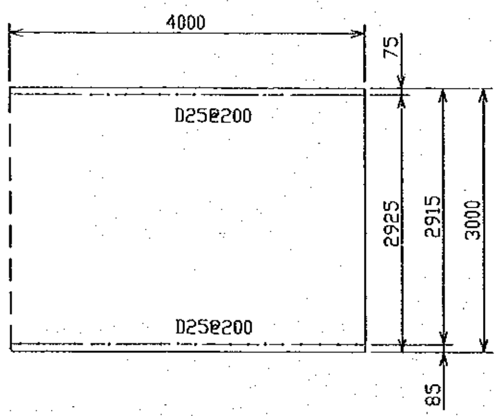
		unit	The vertical direction to the face line		The parallel direction to the face line	
			upper	lower	upper	lower
reinforcing bar		mm	D25	D25	D25	D25
diameter	ϕ	mm	25	25	25	25
covering	c	mm	77	97	52	72
distance between centers of bar	C_s	mm	200	200	200	200
moment (permanent load)	M_e	kN・m	648.00	1,152.00	648.00	1,152.00
moment (variable load)	M_e	kN・m	1,906.00	2,070.00	2,006.00	2,005.50
moment (design load)	M_e	kN・m	1,601.00	2,187.00	1,651.00	2,154.75
area of reinforcing bar (tension side)	A_s	cm^2	101.34	101.34	101.34	101.34
effective depth	d	mm	2,910	2,890	2,935	2,915
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	56.31	77.40	57.51	75.52
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	22.79	40.77	22.57	40.37
flexural crack width (design load)	w1	mm	0.186	0.274	0.145	0.217
flexural crack width (permanent load)	w2	mm	0.114	0.181	0.087	0.144
permisible crake width	w_a	mm	0.308	0.340	0.208	0.252
Examination result (design load)			$w1 < w_a$ O.K	$w1 < w_a$ O.K	$w1 < w_a$ O.K	$w1 < w_a$ O.K
Examination result (permanent load)			$w2 < w_a$ O.K	$w2 < w_a$ O.K	$w2 < w_a$ O.K	$w2 < w_a$ O.K

・Dimension of an examination section

The vertivcal direction to the face line



The parallel direction to the face line



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b) Examination of Shear Cracks

For members subject to shear forces, it may not be required to examine shear cracks when the design shear force, Vd, is smaller than 70% of the design shear capacity of concrete, Vcd. When examination for shear crack is necessary, the stress in shear reinforcement due to permanent load is confirmed smaller than the limiting value for the increment in stress in ordinary reinforcement due to permanent load.

$$\sigma wpd = \frac{(Vpd + Vrd - k_2 \times Vcd) \times s}{Aw \times z \times (\sin \alpha s + \cos \alpha s)} \times \frac{Vpd + Vcd}{Vpd + Vrd + Vcd}$$

wher 、 σ wpd : design stress in shear reinforcement due to permanent load

Vpd : design shear force produced by permanent load

Vrd : design shear force produced by variable load

Vcd : design shear capacity of concrete
(see examination of shearing force of ultimate limit state
It considers as $\gamma b = \gamma c = 1.0$)

Aw : area of one unit of shear reinforcement

s : spacing of shear reinforcement

z : distance from compression resultant to centroid of tension reinforcement (=d/1.15)

d : effective depth

α s : angle between shear reinforcement and axis of member

k_2 : The factor for taking into consideration the influence of the frequency of change load (=0.5)

The limiting value for the increment in stress in ordinary reinforcement due to permanent load " σ sp" uses the following values. (see "Standard Specifications of Concrete (in Japan))

When a upper side reinforcing bar steel rod is examined σ sp = 100 N/mm^2

When a lower side reinforcing bar steel rod is examined σ sp = 80 N/mm^2

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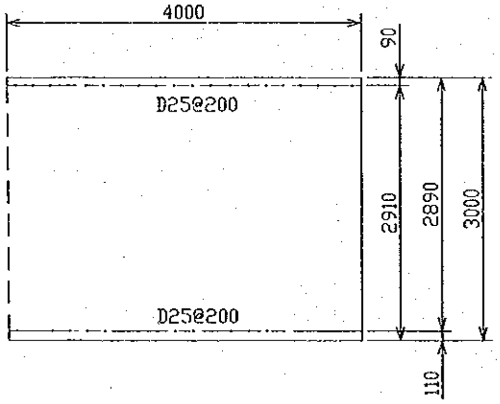
Examination shearing crack

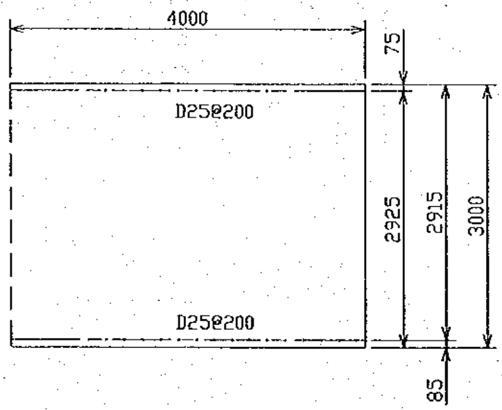
		unit	The vertical direction to the face line	The parallel direction to the face line
reinforcing bar			D25	D25
number of reinforcing bar			20	20
area of reinforcing bar (tension side)	A_s	cm^2	101.34	101.34
width of member	b_w	mm	4,000	4,000
effective depth	d	mm	2,890	2,915
compression force of an axis	N'_d	kN	0	0
design shear capacity of concrete	V_{cd}	kN	3,762.56	3,773.25
design shear force	V_d	kN	1,836.68	1,841.15
Examination result (V_d/V_{cd})			0.809	0.808
Necessity for examination of shear crack			with necessity	with necessity
σ wpd			62.88	62.44
σ sp			80.00	80.00
Judgmrnt			O.K	O.K

・Dimension of an examination section

The vertivcal direction to the face line



The parallel direction to the face line



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7) Design of Pile Head

Examination of a pile head portion is calculated by ultimate limit state.

(1) Section Force

Maximum axial force $Sd = 2,560.00$ kN

(Mooring Condition、Traction direction : 45° direction to the face line、LWL)

Maximum tensile force $Sd = -476.50$kN

(Mooring Condition、Traction direction : 45° direction to the face line、LWL)

Maximum pile head moment $M_0 = 2,073.60$ kN・m

(Mooring Condition、Traction direction : 45° direction to the face line、LWL)

(2) Examination of Pushing Force

To punching force which acts on superstructure, it resists by punching shear capacity. Examination to pushing force is performed by the following formula.

$$\gamma_i \times \frac{S_d}{V_{pcd}} \leqq 1.0$$

γ_i ; structure factor (Mooring Condition : 1.20)

S_d ; punching force (N)

V_{pcd} ; design punching shear capacity (N)

$$V_{pcd} = \beta_d \times \beta_p \times \beta_r \times f_{pcd} \times u_p \times d' / \gamma_{bc}$$

$$f_{pcd} = 0.20 \times (f'_{cd})^{1/2}$$

β_d ; coefficiect to consider influence of effective depth on shea capacity

$$\beta_d = (1000/d')^{1/4}$$

β_p ; coefficient to consider influence of longitudinal reinforcement on shear capacity $\beta_p = (100 \times P_w)^{1/3}$

β_r ; coefficient to consider influence of loaded area on punching shear capacity $\beta_r = 1 + 1/(1 + 0.25 \times u/d')$

f'_{cd} ; design compressive strength of concrete (N/mm²) $f'_{cd} = f'_{ck} / \gamma_{mc}$

f'_{ck} ; characteristic compressive strength of concrete (N/mm²)

γ_{mc} ; material factor of concrete (=1.3)

u_p ; peripheral length of the design cross section which is located d/2 from the loaded area

d' ; Distance from the pile head upper surface to reinforcing bar in tensile zone (mm)

p_w ; reinforcement ratio which are defined as the average values for the reinforcement in two directions $p_w = As/(b_w \times d)$

As ; area of reinforcing bar in tensile zone (mm²)

b_w ; web width of member (mm)

d ; effective depth (mm)

u ; perimeter of pile (m)

γ_{bc} ; material factor for concrete without reinforcement (=1.30)

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Examination Result of Punching Shear

Design Punching Shear Capacity			unit	Mooring Condition(LWL) 45° direction to the face line
Material factor for concrete		γ m		1.30
Member factor for superstructure		γ b		1.30
Structure factor		γ i		1.20
Reinforcing bar in tensile (vertical direction to the face line)				D25
	d'		mm	2910
Interval of reinforcing bar		@	mm	200
Reinforcing bar in tensile (parallel direction to the face line)				D25
	d'		mm	2935
Interval of reinforcing bar		@	mm	200
ratio of tension reinforcement	(vertical direction to the face line)	pw1		0.00087
	(parallel direction to the face line)	pw2		0.00086
	(average)	pw		0.00087
diamete of pile		φ	mm	1,100.00
	d		mm	1,500.00
	u		mm	3,455.75
	f'ck		N/mm2	24.00
	f'cd		N/mm2	18.46
	β d			0.90
	β p			0.44
	β r			1.63
$fpcd = 0.20\times(f'cd)^{1/2}$		fpcd	N/mm2	0.86
	up		mm	8,168.14
	Vpcd		kN	5,294.17
	Sd		kN	2,560.00
Examination result		γ i×Sd / Vpcd		0.58

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(3) Examination to pile head moment

The necessity embedding length to pile head moment computes from the following formulas.

$L = \sqrt{(6 \times M_0 / (B \times f'ad))} \times \gamma b \times \gamma i$

where L : necessity embedding length to pile head moment (mm)

M_0 : pile head moment (= 2,073,600,000 N・mm)

B : diameter of the pile (= 1,100 mm)

f'ad : design bearing strength of superstructure

(The same value as the design compression strength of concrete)

(= 24 / 1.3 = 18.46 N/mm²)

γb : member factor (=1.15)

γi : structure factor (=1.20)

$L = \sqrt{(6 \times 2{,}073{,}600{,}000 / (1{,}100 \times 18.46))} \times 1.15 \times 1.20 = 1{,}080$ mm

(4) Examination to pulling force

The necessity embedding length to pulling force computes from the following formulas.

$L = P / (\phi \times fbod / \gamma b)$

where P : calculated value of axial force acting on pile in design

(=Sd=476,500 N)

ϕ : outer perimeter of the cross section of pile (diameter : 1,100 mm)

fbod : design bond strength between the pile and concrete

$(=0.11 \times f'ck^{2/3} / \gamma c = 0.11 \times 24^{2/3} / 1.3 = 0.704\ N/mm^2)$

f'ck : characteristic compressive strength of concrete

γc : material factor for concrete

γb : member factor

$L = 476{,}500 / (1{,}100 \times \pi \times 0.704 / 1.0) = 196$ mm

(4) Determination of the embedding length of piles

The embedding length to superstructure of a steel pipe pile does as follows from the above-mentioned examination result.

L = 1,500 mm (The pile is embedded to the center of superstructure.)

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8) Examination of welding of reinforcing bar and steel pipe pile

The lower reinforcing bar of a beam is welded to the plate attached in the steel pipe pile. The diameter and number of lower reinforcing bar of the parallel and vertical directions beam to the face line are as follows.

Diameter : D25 、 Number : 5 pieces

(1) Examination of thickness of plate

The thickness (t) of a plate is calculated by the following formula.

$t = T / (L \times \tau_{ta})$ (mm)

where T : Action tension (N)

$T = As \times \sigma_{sa} \times n$

As : cross-section area of reinforcing bar (mm^2) (D25 As = 506.7mm^2)

σ_{sa} : allowable stress of reinforcing bar (SD345 : =176 N/mm^2)

n : number of reinforcing bar (=5 pieces)

L : Welding length of a plate

τ_{ta} : allowable tensile stress for steel at welded zone (SM400 =140 N/mm^2)

・Welding length of a plate

The outer perimeter of steel pipe pile is 800mm, and a plate is divided into four.

$L = \pi \times 1{,}100 / 4 = 863.9$ m

・Action tension

$T = 506.7 \times 176 \times 5 = 535{,}075$ N

・Thickness of plate

$t = 535{,}075 / (863.9 \times 140) = 4.4$ mm → 9.0mm

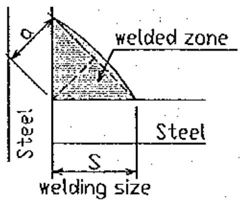
(2) Examination of the welding of steel pipe pile and a plate

Welding size is made into what satisfies the following formulas.

$\tau_{ts} = T / (a \times L) \leqq \tau_{ta}$

The sign of an upper formula is shown in the right figure.

where $a = 0.7 \times a$



Welding size is set to 9mm.

$\tau_{ts} = 535{,}075 / (0.7 \times 9 \times 863.9) = 98.3$ N/mm^2 $\leqq$ 140 N/mm^2 O.K

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(3) Examination of the welding of a plate pile and reinforcing bar

The welding length of reinforcing bar computes by the following formulas.

$l = \sigma_{sa} \times As / (\sqrt{2} \times \lambda \times \tau_{sa})$

where λ : welding size (=D / 3 D : diameter of reinforcing bar)

τ_{sa} : allowable shearing stress for steel at welded zone (= 80 N/mm²)

$l = 176 \times 506.7 / (\sqrt{2} \times (25 / 3) \times 80) = 94.6$ mm

Therefore, welding length is set to l = 100 mm.

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DESIGN CALCULATION COVER SHEET

Project	Detailed Design on Port Reactivation Project in La Union Province	**Project Code**	JC1N004
Section	**Civil**	Calc. File No.	
Sub-Section	**Quaywall**	Calc. Index No.	

Subject: **Passenger Berth**

Calculation Objective:

Rainforcement of platform 1.

References, Calculation Notes and Comments

Refer to drawings **QW-02-008～QW-02-011**

Calculation based on

TECHNICAL STANDERDS AND COMMENTARIES

FOR

PORT AND HARBOUR FACILITIES IN JAPAN

Rev	Prepared		No. of	Checked		Reviewed		Superseded
	by	Date	Pages	by	Date	by	Date	by Calc No.
O	[signature]	26/07/02	63	[signature]	26 July 02	[signature]	26/08/02	
A								
B								
C								

File in Calc. File

7 . Detail Designn of Platform1 (Passenger Berth)

1) Examination Case

Combination of the load of the examination case of calculation of reinforcing bar arrangement, and each examination case

	Deadweight	Surcharge	Earthquake force	Wheel load (Truck)
Ordinary	○	○	—	—
Earthquake	○	○	○	—
Wheel Load (truck)	○	—	—	○

Moreover, calculation of reinforcing bar arrangement of each examination case is performed as follows.

	Ultimate limit	Serviceability limit	Fatigue limit
Ordinary	○	○	—
Earthquake	○	—	—
Wheel Load (truck)	○	○	○

2) Partial Safety Factors

The partial safety factor used for this examination is shown below.

(1) Load Factor

	Ulitimate limit	Serviceability limit	Fatigue limit
Deadweight	1. 1	1. 0	1. 0
Surcharge	1. 2 (1. 0)	1. 0	1. 0
Wheel Load (truck)	1. 2	1. 0	1. 0
Earthquake Force	1. 0	—	—

※The inside of a parenthesis is a value in case of an earthquake.

(2) The other numbers of Partial Safety Factor

		Ulitimate limit	Serviceability limit	Fatigue limit
Material factor (γ m)	Concrete	1.30	1.00	1.30
	Reinforcing Bar	1.00	1.00	1.05
Structural analysis factor(γ a)		1.00	1.00	1.00
Member factor (γ b)		1.15～1.30	1.00	1.00
Structure factor (γ i)		Earthquake 1.00 Otherwise 1.20	1.00	1.00

※Member factor

When calculating bending and axial strength : 1.15

When calculating upper limit of axial compressive strength : 1.30

When calculating shear capacity borne by concrete : 1.30

When calculating shear capacity borne by shear reinforcement : 1.15

3) Calculation Method of Cross-Sectional Force

(1) Beam

The cross-sectional force of a beam is computed using a 2-dimensional framework model (continuation beam). Action load is multiplied by the partial safety factor. The calculation result computed by the basic design is used for the pile head moment in case of an earthquake.

(2) Deck Slab

The deck slab of the platform central part surrounded by the beam should be designed as a slab fixed on four sides. The deck slab of a platform end should be designed as a slab fixed on three sides and free on one side.

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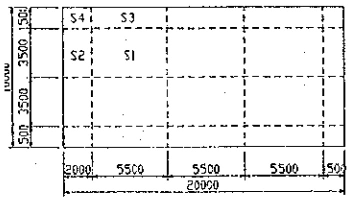
4) Calculation of Load

(1) Deck Slab

The examination cases of calculation of reinforcing bar arrangement of a deck slab are the following two cases.



・Ordinary Condition ・Conditions on which Wheel Load(Truck) acts

Cross-sectional force is computed only about "S1" and "S3". Examination is omitted about "S2" and "S4", and it is made the same reinforced bar arrangement as "S1" and "S3", respectively. (see upper figure)

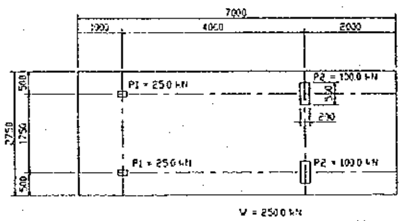
a) Deadweight Thickness of deck slab t=0.25cm

Equivalent uniform distribution $w = 0.25 \times 24.0 = 6.00$ kN/m^2

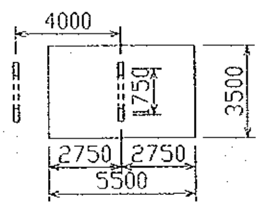
b) Surcharge $w = 20.0$ kN/m^2

c) Wheel Load (Truck)

Wheel load (Truck) is converted into equivalent uniform distribution and partial equivalent uniform distribution. Section force is computed about each distribution load, and the larger one is made into design section force.



Wheel load (Truck) shall act only on "S1" of the member of deck slab. The action situation of wheel load (Truck) is shown below.



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(i) Conversion to equivalent uniform distribution load

Wheel load is converted into equivalent uniform distribution load "w1" using the following formulas.

$$w1 = \frac{P}{C \times (0.50 \times L_1 + 0.25 \times L_2)}$$

where P : Wheel Load (2×100 = 200 kN)

C : Width of Truck (= 2.75 m)

L_1 : Length of the longer side (= 5.50m)

L_2 : Length of the shorter side (= 3.50m)

$w1 = 200 / (2.75 \times (0.50 \times 5.50 + 0.25 \times 3.50)) = 20.06\ kN/m^2$

(ii) Conversion to partial equivalent uniform distribution load

Wheel load acts as the following figures and computes conversion distribution width as follows.

$u' = u + 2 \times (s + (t/2))$

$v' = v + 2 \times (s + (t/2))$

where

u'、v' : Converted distribution width

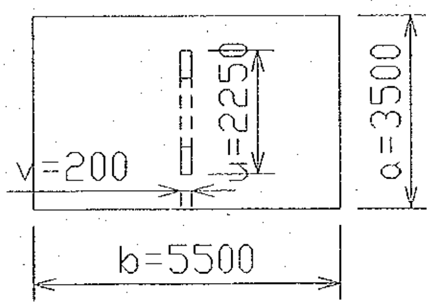
s : Thickness of pavement (This sets up with "=0.10 m")

t : Thickness of deck slab (=0.25 m)

$u' = 2.25 + 2 \times (0.1 + (0.25/2)) = 2.70$ m

$v' = 0.20 + 2 \times (0.1 + (0.25/2)) = 0.65$ m

Wheel Load P = 2×100 = 200 kN



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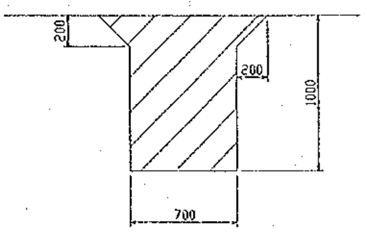
(2) Beam

Calculation of reinforcing bar arrangement of a beam carries out for all examination cases.

a) Deadweight of Beam

The section of a beam is shown below. (Hatching part)



Cross-section area of beam

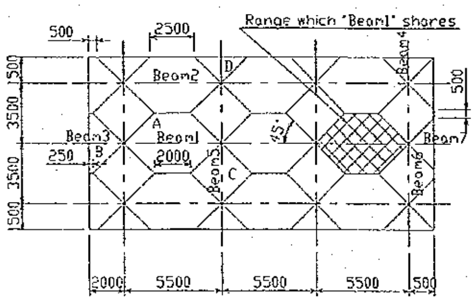
$A = 0.7 \times 1.0 + 0.2^2 / 2 \times 2 = 0.74\ m^2$

Deadweight of beam

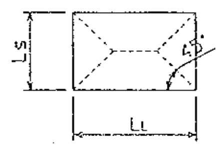
$w = 0.74 \times 24.0 = 17.76$ kN/m

b) Deadweight of Deck Slab

The deadweight of deck slab, which the individual beam shares, is shown in the following figures. Cross-sectional force is computed only about "Beam1", "Beam3", "Beam4", and "Beam5." Examination is omitted about "Beam2","Beam6" and "Beam7" ,and it is made the same reinforced bar arrangement as "Beam1","Beam5" and "Beam3", respectively.



The deck slab weight, which the individual beam shares, is converted into equivalent uniform distribution load by the following formulas.



Converted equivalent uniform distribution load of short span

$W = w \times Ls / 3$ (kN/m)

Converted equivalent uniform distribution load of long span

$W = (w \times Ls / 2) \times (1 - (1/3) \times (Ls^2 / L_L^2))$ (kN/m)

where w : Deadweight of deck slab (kN/m²)

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Ls : Length of short span (m)、 L_L : Length of long span (m)

The deadweight of deck slab member"A～D" in the figure of a front page is converted into equivalent uniform distribution load.

Load which acts on a long span beam (A、B)

	Length of long span L_L (m)	Length of short span Ls (m)	Deadweight of deck slab (kN/m^2)	Equivalent uniform distribution load(deck slab) (kN/m)
A	5.50	3.50	6.00	9.08
B	4.00	3.50	6.00	7.82

※About "B", it computed by having set up with the same range as "A."

The long span length of "B" L_L= 2×2.0=4.0m。

Load which acts on a short span beam (C、D)

	Length of short span Ls (m)	Deadweight of deck slab (kN/m^2)	Equivalent uniform distribution load(deck slab) (kN/m)
C	3.50	6.00	7.00
D	3.00	6.00	6.00

Therefore, the deadweight of deck slab, which acts on the beam to examine, becomes as follows.

Beam1 w = 9.08 + 9.08 = 18.16 kN/m (A+A)

Beam3 w = 7.82 + 7.82 = 15.64 kN/m (B+B)

Beam4 w = 6.00 + 6.00 = 12.00 kN/m (D+D)

Beam5 w = 7.00 + 7.00 = 14.00 kN/m (C+C)

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c) Surcharge

The surcharge which acts on a beam is computed like the deadweight of deck slab. Load which acts on a long span beam (A、B)

	Length of long span L_L (m)	Length of short span L_S(m)	Surcharge (Ordinary) (kN/m^2)	Surcharge (Earthquake) (kN/m^2)	Equivalent uniform distribution load (Ordinary) (kN/m)	Equivalent uniform distribution load (Earthquake) (kN/m)
A	5.50	3.50	20.00	10.00	30.28	15.14
B	4.00	3.50	20.00	10.00	26.07	13.03

Load which acts on a short span beam (C、D)

	Length of short span L_S(m)	Surcharge (Ordinary) (kN/m^2)	Surcharge (Earthquake) (kN/m^2)	Equivalent uniform distribution load (Ordinary) (kN/m)	Equivalent uniform distribution load (Earthquake) (kN/m)
C	3.50	20.00	10.00	23.33	11.67
D	3.00	20.00	10.00	20.00	10.00

Therefore, the surcharge, which acts on the beam to examine, becomes as follows.

Beam1 (Ordinary) w = 30.28 + 30.28 = 60.56 kN/m (A+A)

Beam1 (Earthquake) w = 15.14 + 15.14 = 30.28 kN/m (A+A)

Beam3 (Ordinary) w = 26.07 + 26.07 = 52.14 kN/m (B+B)

Beam3 (Earthquake) w = 13.03 + 13.03 = 26.06 kN/m (B+B)

Beam4 (Ordinary) w = 20.00 + 20.00 = 40.00 kN/m (D+D)

Beam4 (Earthquake) w = 10.00 + 10.00 = 20.00 kN/m (D+D)

Beam5 (Ordinary) w = 23.33 + 23.33 = 46.66 kN/m (C+C)

Beam5 (Earthquake) w = 11.67 + 11.67 = 23.34 kN/m (C+C)

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d) Wheel Load (Truck)

The truck, which runs platform1, shall run only the vertical direction to the face line. Moreover, the truck, which runs in parallel, makes two sets the maximum.

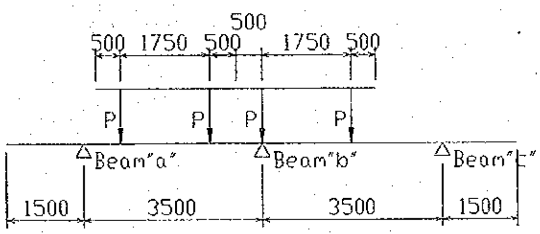
The maximum reaction force of acting on a beam is computed out of various run situations. Wheel load (Truck) acts on "beam1" and "beam5". As for "Beam3" and "Beam4", wheel load (truck) shall not act.

(i) Beam of Vertical Direction to the Face Line (Beam1)

・Calculation of the maximum reaction force which acts on beam of vertical direction to the face line

Arrangement of the truck which maximum reaction force generates on the beam of vertical direction to the face line is shown in the following figures.

(Rear wheel P = 100 kN、Front wheel P = 25 kN)



The beam on which maximum reaction force acts is Beam "b".

Maximum reaction force

$$R = (0.75 \times 100 / 3.50) + (2.50 \times 100 / 3.50) + (1.75 \times 100 / 3.50) + 100$$

$$= 242.86 \text{ kN (Rear wheel)} \quad (\text{Front wheel} \quad R = 60.71 \text{ kN})$$

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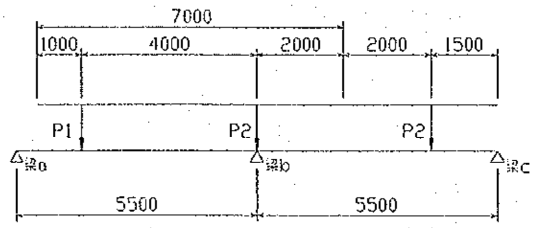
(ii) Beam of Parallel Direction to the Face Line (Beam5)

- Calculation of the maximum reaction force which acts on beam of vertical direction to the face line

Arrangement of the truck which maximum reaction force generates on the beam of vertical direction to the face line is shown in the following figures.

(P1 = 25 kN、P2 = 100 kN)



The beam on which maximum reaction force acts is Beam "b".

Maximum reaction force

$$R = (1.50 \times 25 / 5.50) + (1.50 \times 100 / 5.50) + 100$$
$$= 134.09 \text{ kN}$$

(iii) Weight of a small beam (The beam of the front of a platform)

$$P = 1.0 \times 0.5 \times 3.50 \times 24.0 = 42.00 \text{ kN}$$

e) Earthquake Force

The pile head moment computed by the basic design is used.

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5) Calculation of the Section Force

(1) Deck Slab

The design of a deck slab calculates "S1" and "S3" as follows.

S1 : a slab fixed on four side

S3 : a slab fixed on three sides and free on one side

Wheel load (Truck) is converted into equivalent uniform distribution and partial equivalent uniform distribution. Section force is computed about each distribution load, and the larger one is made into design section force.

a) Calculation of the Section Force by Equivalent Uniform Distribution Load

Cross-sectional force in case the equivalent uniform distribution load acts on a deck slab is computed using the following formulas.

$Mx = X \times w \times L^2$: the bending moment of X-direction of an axis

$My = Y \times w \times L^2$: the bending moment of Y-direction of an axis

$S = Q \times w \times L$: the shearing force

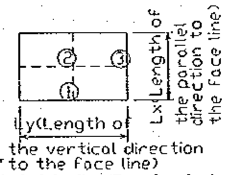
where X、Y : the moment factors of each direction of an axis

w : equivalent uniform distribution load, such as acting on a deck slab

L : length of the short span of a deck slab

Q : the shearing force factors

Cross-sectional forces by the load (deadweight, surcharge, and wheel load (track)), which act on the deck slab, are calculated. A calculation position and a calculation result are shown below.



Deadweight : $w = 6.00$ kN/m²

Surcharge : $w = 20.00$ kN/m²

Wheel load(Truck) : $w = 20.06$ kN/m²

○T... y equivalent uniform distribution load (kN・m/m)

deck slab	Lx (m)	Ly (m)	λ	position	Factor		Deadweight		Surcharge		Wheel Load (Truck)	
					X	Y	Mx	My	Mx	My	Mx	My
S1	3.50	5.50	0.50	1	-0.0828	-0.0138	-6.09	-1.01	-20.29	-3.38	-20.35	-3.39
	3.50	5.50	0.50	2	0.0407	0.0105	2.99	0.77	9.97	2.57	10.00	2.58
	3.50	5.50	0.50	3	-0.0095	-0.0570	-0.70	-4.19	-2.33	-13.97	-2.33	-14.01
S3	1.50	5.50	0.30	1	-0.3819	-0.0636	-5.16	-0.86	-17.19	-2.86		
	1.50	5.50	0.30	2	-0.0434	0.0204	-0.59	0.28	-1.95	0.92		
	1.50	5.50	0.30	3	-0.0249	-0.1495	-0.34	-2.02	-1.12	-6.73		

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○The shearing force by equivalent uniform distribution load (kN/m)

deck slab	Lx (m)	Ly (m)	λ	position	Factor		Deadweight		Surcharge		Wheel load (Truck)	
					X	Y	Mx	My	Mx	My	Mx	My
S1	3.50	5.50	0.50	1	0.4620		9.70		32.34		32.44	
	3.50	5.50	0.50	3		0.5170		10.86		36.19		36.30
S3	1.50	5.50	0.30	1	1.0200		9.18		30.60			
	1.50	5.50	0.30	3		1.3400		12.06		40.20		

b) Calculation of the Section Force by Partial Equivalent Uniform Distribution load

The section force by partial equivalent uniform distribution load is calculated only to the wheel load (Truck). The section force is calculated using the graph for calculating of Pigeaud.

Length of short span (the vertical direction to the face line) a = 3.50 m

Length of long span (the parallel direction to the face line) b = 5.50 m

Width of wheel (the direction to short span) u' = 2.70 m

Width of wheel (the direction to long span) v' = 0.65 m

u' / a = 0.771、 v' / b = 0.118、 $\rho = 3.5 / 5.5 = 0.636 \rightarrow 0.60$

Wheel Load P = 200 kN

The bending moment of a deck slab is computed using the following formulas.

$Mx = 0.8 \times (M1 + \eta \times M2) \times P$

$My = 0.8 \times (M2 + \eta \times M1) \times P$

where Mx : the bending moment of the parallel direction to the face line

(By this examination, it is the direction of short span.)

My : the bending moment of the vertical direction to the face line

(By this examination, it is the direction of long span.)

M1、M2 : The distribution factor of a bending moment

η : poisson's ratio (=0.15 (reinforced concrete))

The shearing force is computed using the following formulas.

In the case of "u > v"

The shearing force of the direction of short span $Su = P / (2 \times u + v)$

The shearing force of the direction of long span $Sv = P / (3 \times u)$

In the case of "u < v"

The shearing force of the direction of short span $Su = P / (3 \times v)$

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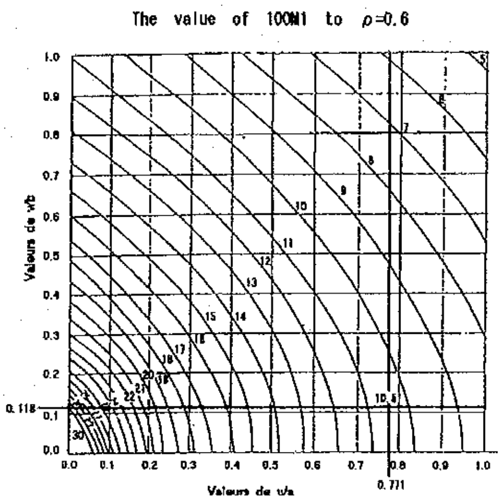
The shearing force of the direction of long span $Sv = P / (2 \times v + u)$

○Section Force(Wheel Load) by Partial Equivalent Uniform Distribution load

deck slab	Wheel load (kN)	M1 (kN・m/m)	M2 (kN・m/m)	Mx (kN・m/m)	My (kN・m/m)	Sx (kN/m)	Sy (kN/m)
S1	200	0.105	0.095	19.08	17.72	33.06	24.69

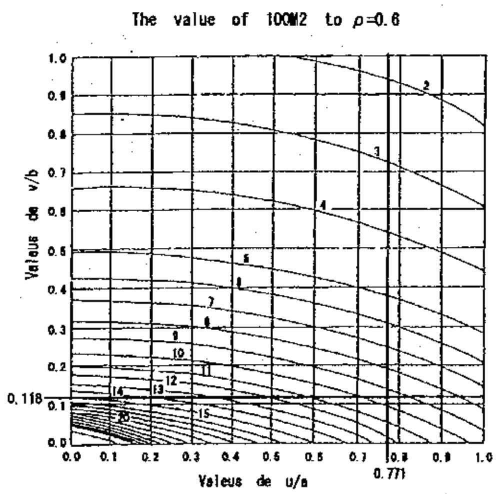
The bending moment distribution factor of the direction of short span (the vertical direction to the face line) : M1



$100 \times M1 = 10.5$

Therefore, $M1 = 0.105$

The bending moment distribution factor of the direction of short span (the vertical direction to the face line) : M2



$100 \times M2 = 9.5$

Therefore、 $M2 = 0.095$

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c) Generalization of Section Force

Generalization of the section force of deck slab "S1"

	Bending moment (kN・m/m)				Shearing force (kN/m)	
	Parallel to the face line Mx		Vertical to the face line My		Parallel to the face line Sx	Vertical to the face line Sy
	Fulcrum	Center	Fulcrum	Center		
Deadweight (D)	-6.09	2.99	-4.19	0.77	9.70	10.86
Surcharge (S)	-20.29	9.97	-13.97	2.57	32.34	36.19
Equivalent Uniform Distribution load (M1)	-20.35	10.00	-14.01	2.58	32.44	36.30
Partial Equivalent Uniform Distribution load (M2)	-19.08	19.08	-17.72	17.72	33.06	24.69
Ultimate limit state						
Ordinary 1.1D+1.2S	-31.05	15.25	-21.37	3.93	49.48	55.37
Wheel Load(truck) 1.1D+1.2M1	-31.12	15.29	-21.42	3.94	49.60	55.51
Wheel Load(truck) 1.1D+1.2M2	-29.60	26.19	-25.87	22.11	50.34	41.57
Serviceability limit state						
Permanent Load 1.0D	-6.09	2.99	-4.19	0.77	9.70	10.86
Variable Load 1.0S	-20.29	9.97	-13.97	2.57	32.34	36.19
1.0M1	-20.35	10	-14.01	2.58	32.44	36.3
1.0M2	-19.08	19.08	-17.72	17.72	33.06	24.69
Fatigue limit state						
Permanent Load 1.0D	-6.09	2.99	-4.19	0.77	9.7	10.86
Variable Load 1.0M1	-20.35	10	-14.01	2.58	32.44	36.3
1.0M2	-19.08	19.08	-17.72	17.72	33.06	24.69

Generalization of the section force of deck slab "S3"

	Bending moment (kN・m/m)				Shearing force (kN/m)	
	Parallel to the face line Mx		Vertical to the face line My		Parallel to the face line Sx	Vertical to the face line Sy
	Fulcrum	Center	Fulcrum	Center		
Deadweight (D)	-5.16	—	-2.02	0.28	9.18	12.06
Surcharge (S)	-17.19	—	-6.73	0.92	30.60	40.20
Ultimate limit state						
Ordinary 1.1D+1.2S	-26.30	—	-10.30	1.41	46.82	61.51
Serviceability limit state						
Permanent Load 1.0D	-5.16	—	-2.02	0.28	9.18	12.06
Variable Load 1.0S	-17.19	—	-6.73	0.92	30.60	40.20

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※Since the bending moment of the central part of the parallel direction to the face line shows a small value compared with a fulcrum part, it omits examination.

(2) Beam

The section force of a beam computes the vertical and parallel direction beam to the face line as a continuation beam.

the vertical direction beam to the face line : Beam 1 +Beam 3

the parallel direction beam to the face line : Beam 5 +Beam 4

When wheel load acts on cantilever of the end by the side of land, big section force occurs near the pile by the side of land. Therefore, cantilever by the side of land calculates separately with the above-mentioned beam.

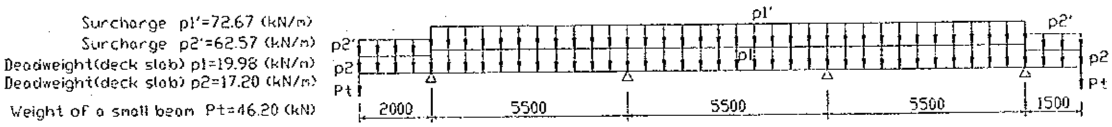
a) Ultimate Limit State

(i) Ordinary

Load which acts(Ordinary) 1.1D (Deadweight) + 1.2S (Surcharge)

①The vertical direction beam to the face line

A frame model is shown below. (Deadweight of a beam is taken into consideration.)



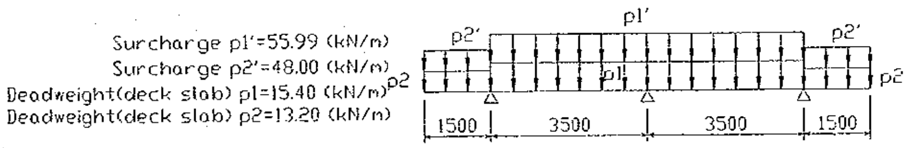
Maximum bending moment upper side Mmax = 310.49 kN・m

lower side Mmax = 180.92 kN・m

Maximum shearing force Smax = 332.05 kN

②The parallel direction beam to the face line

A frame model is shown below. (Deadweight of a beam is taken into consideration.)



Maximum bending moment upper side Mmax = 93.82 kN・m

lower side Mmax = 46.91 kN・m

Maximum shearing force Smax = 159.97 kN

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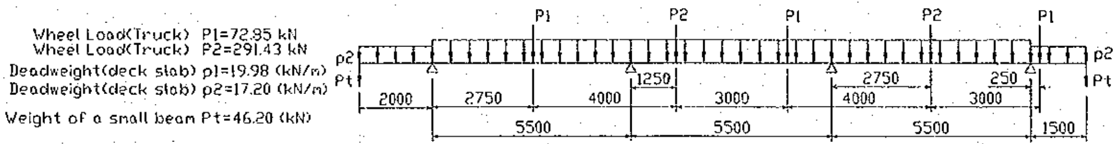
(ii) Wheel Load (Truck)

Load which acts(Wheel Load) 1.1D (Deadweight) + 1.2M (Wheel Load(Truck))

①The vertical direction beam to the face line

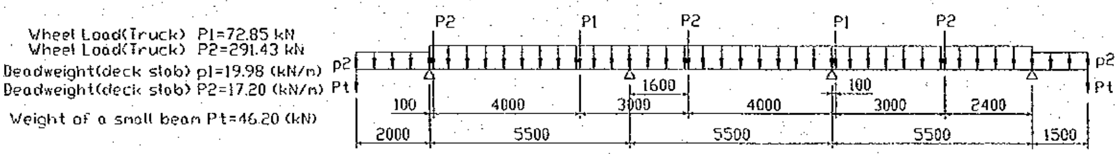
A frame model is shown below. (Deadweight of a beam is taken into consideration.)

・Upper reinforcing bar



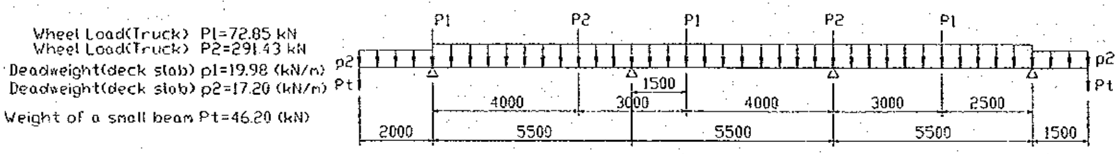
Maximum bending moment upper side Mmax = 332.87 kN・m

・Lower reinforcing bar



Maximum bending moment lower side Mmax = 341.77 kN・m

・Shearing force



Maximum shearing force Smax = 435.07 kN・m

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②The parallel direction beam to the face line

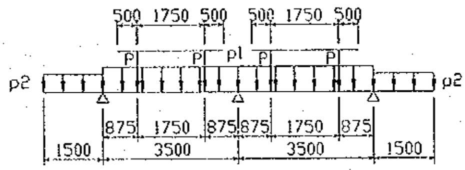
A frame model is shown below. (Deadweight of a beam is taken into consideration.)

Upper reainforcing bar

Wheel Load(Truck) P=160.91 kN

Deadweight(deck slab) p1=15.40 (kN/m)

Deadweight(deck slab) p2=13.20 (kN/m)

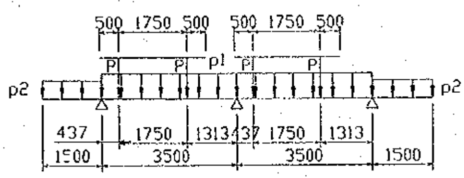


Lower reinforcing bar

Wheel Load(Truck) P=160.91 kN

Deadweight(deck slab) p1=15.40 (kN/m)

Deadweight(deck slab) p2=13.20 (kN/m)



Maximum bending moment upper side Mmax = 193.48 kN・m

lower side Mmax = 117.85 kN・m

Maximum shearing force Smax = 303.30 kN

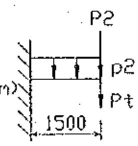
③Cantilever of a land side

A frame model is shown below. (Deadweight of a beam is taken into consideration.)

Wheel Load(Truck) P1=291.43 kN

Deadweight(deck slab) p1=17.20 (kN/m)

Weight of a small beam Pt=46.20 (kN)



Deadweight of beam w' = 0.74×24×1.1 = 19.54 kN/m

All equivalent uniform distribution load w = 19.54 + 17.20 = 36.74 kN/m

Wheel Load + Weight of a small beam P = 291.43+46.20 = 337.63 kN

Maximum bending moment Mmax = $(36.74\times 1.5^2)/2+337.63\times 1.5=547.78$ kN・m

Maximum shearing force Smax = 36.74×1.5 + 337.63 = 392.74 kN

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(iii) Earthquake Condition

Load which acts(Earthquake)

1.1D (Deadweight) +1.0S (Surcharge) +1.0E (Earthquake Force)

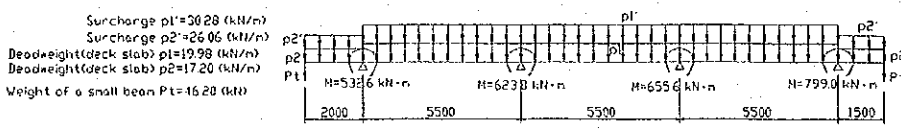
The pile head moment computed by the basic design is used.

①The vertical direction beam to the face line

A frame model is shown below. (Deadweight of a beam is taken into consideration.)

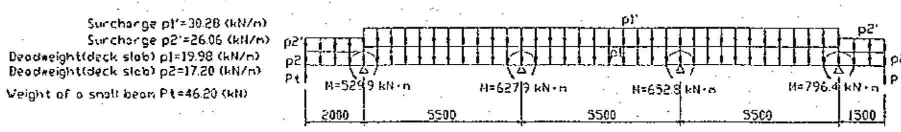
Earthquake

Sea→Land



Earthquake

Land→Sea



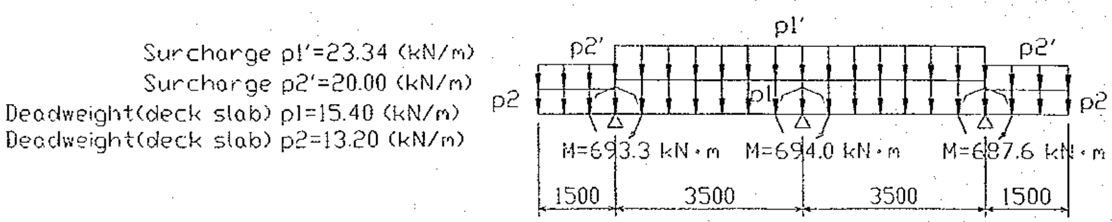
Maximum bending moment upper side Mmax = 938.95 kN・m

lower side Mmax = 661.57 kN・m

Maximum shearing force Smax = 431.58 kN

②The parallel direction beam to the face line

A frame model is shown below. (Deadweight of a beam is taken into consideration.)



Maximum bending moment upper side Mmax = 746.93 kN・m

lower side Mmax = 633.97 kN・m

Maximum shearing force Smax = 399.69 kN

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b) Serviceability Limit State

The Section force of a serviceability limit state is divided and computed when the case where permanent load (Deadweight) acts and variable load (Surcharge, Wheel Load(Truck)) act. Design load is computed using the following formulas.

$$S_k = k_p \times S_p + k_r \times S_r$$

where

S_k : characteristic value of load for examination of the serviceability limit state

S_p : characteristic value of permanent load

S_r : characteristic value of variable load

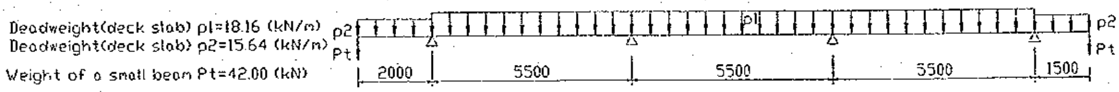
k_p,k_r : constans to represent the effects on crake widths and the corrosion of steel by the permanent load and variable load, respectively. It may be taken that k_p is 1.0 and k_r is 0.5.

(i) Ordinary

①The vertical direction beam to the face line

・Permanent Load (Deadweight)

A frame model is shown below. (Deadweight of a beam is taken into consideration.)



Maximum bending moment upper side Mmax = 150.80 kN・m

lower side Mmax = 52.43 kN・m

Maximum shearing force Smax = 112.54 kN

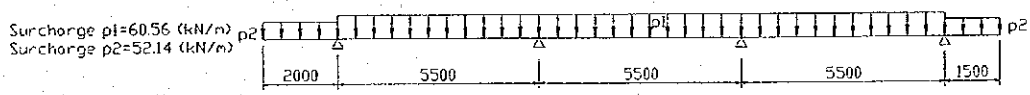
Cantilever of a land side

Maximum bending moment Mmax = 100.58 kN・m

Maximum shearing force Smax = 100.36 kN

・Variable Load (Surcharge)

A frame model is shown below. (Deadweight of a beam is taken into consideration.)



Maximum bending moment upper side Mmax = 174.50 kN・m

lower side Mmax = 116.08 kN・m

Maximum shearing force Smax = 187.60 kN

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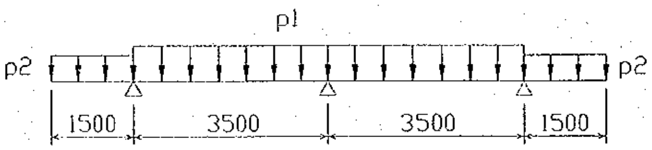
②The parallel direction beam to the face line

Deadweight(deck slab) p1=14.00 (kN/m)
Deadweight(deck slab) p2=12.00 (kN/m)



- Permanent Load (Deadweight)

A frame model is shown below. (Deadweight of a beam is taken into consideration.)

Maximum bending moment upper side Mmax = 33.48 kN・m

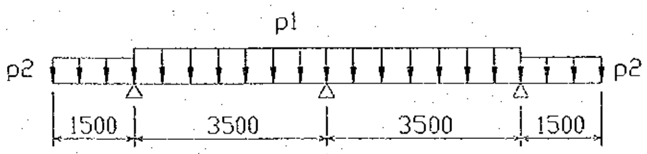
lower side Mmax = 15.95 kN・m

Maximum shearing force Smax = 56.03 kN

- Variable (Surcharge)

A frame model is shown below. (Deadweight of a beam is taken into consideration.)

Surcharge p1=46.66 (kN/m)
Surcharge p2=40.00 (kN/m)



Maximum bending moment upper side Mmax = 48.95 kN・m

lower side Mmax = 24.49 kN・m

Maximum shearing force Smax = 82.78 kN

(ii) Wheel Load (Truck)

①The vertical direction beam to the face line

- Permanent Load (Deadweight)

The same value as the ordinary condition computed value is used.

Maximum bending moment upper side Mmax = 150.80 kN・m

lower side Mmax = 52.43 kN・m

Maximum shearing force Smax = 112.54 kN

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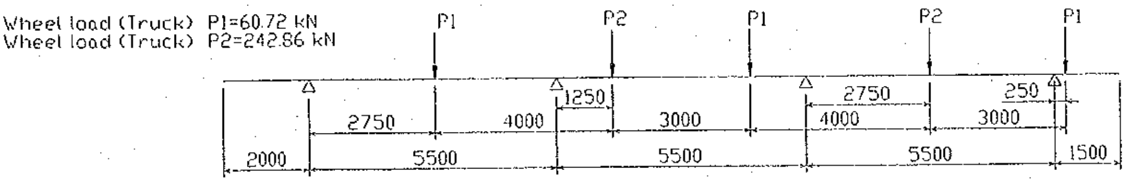
・Variable Load (Wheel Load (Truck))

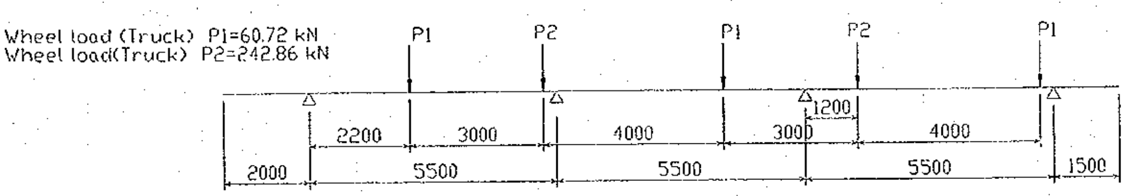
A frame model is shown below. (Deadweight of a beam is taken into consideration.)

(Reinforcing bar of upper side)



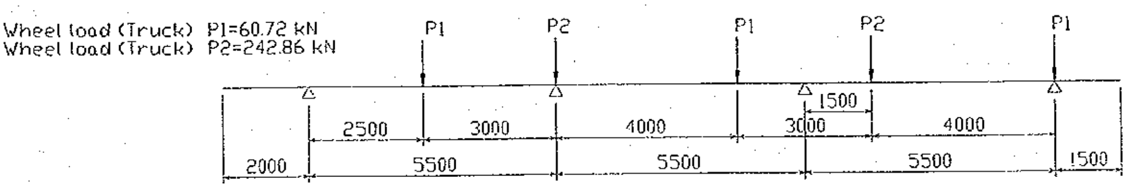
Maximum bending moment upper side Mmax = 201.25 kN・m

(Reinforcing bar of lower side)



Maximum bending moment lower side Mmax = 252.45 kN・m

(Shearing)



Maximum shearing force Smax = 273.45 kN

②The parallel direction beam to the face line

・Permanent Load (Deadweight)

The same value as the ordinary condition computed value is used.

Maximum bending moment upper side Mmax = 33.48 kN・m

lower side Mmax = 15.95 kN・m

Maximum shearing force Smax = 56.03 kN

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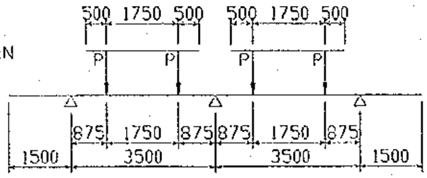
・Variable Load (Wheel Load (Truck))

A frame model is shown below. (Deadweight of a beam is taken into consideration.)

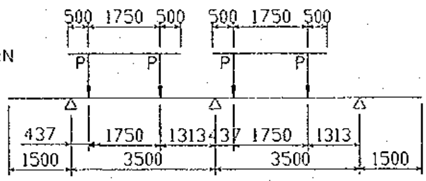
Reinforcing bar of upper side

Wheel load (Truck) P=134.09 kN



Reinforcing bar of lower side

Wheel load (Truck) P=134.09 kN



Maximum bending moment upper side Mmax = 131.97 kN・m

lower side Mmax = 86.55 kN・m

Maximum shearing force Smax = 202.21 kN

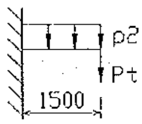
③Cantilever of a land side

・Permanent Load (Deadweight)

A frame model is shown below.

Deadweight(deck slab) p2=15.64 (kN/m)

Weight of a small beam Pt=42.00 (kN)



Deadweight of beam w = 0.74 × 24 = 17.76 kN/m

All equivalent uniform distribution load w = 17.76 + 15.64 = 33.40 kN/m

Weight of a small beam Pt = 42.00 kN

Maximum bending moment Mmax = $(33.40 \times 1.5^2)/2 + 42.00 \times 1.5 = 100.58$ kN・m

Maximum shearing force Smax = $33.40 \times 1.5 + 42.00 = 92.10$ kN

		Prepared by	Y. Ando	Checked by	R. NISHIMURA
			21/07/2002		08/08/2002

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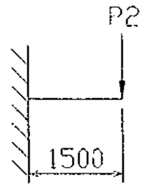
・Variable Load (Wheel Load (Truck))

A frame model is shown below.



Maximum bending moment $M_{max} = 242.86 \times 1.5 = 364.29$ kN・m

Maximum shearing force $S_{max} = 242.86$ kN

c) Fatigue Limit State

The examination case of a fatigue limit state is only Wheel Load (Truck).

The section force of using by examination of a fatigue limit state is the same as the section force of using by examination of a serviceability limit state.

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		26/07/2002	08/08/2002

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d) Generalization of the load in each limit state

(i) The vertical direction beam to the face line

・Bending Morment (kN・m)

	Ultimate limit		Serviceability limit			
	upper side	lower side	permanent load		variable load	
			upper	lower	upper	lower
Ordinary	310.49	180.92	150.80	52.43	174.50	116.08
Wheel Load (Truck)	332.87	341.77	150.80	52.43	201.25	252.45
Earthquake	938.95	661.57	—	—	—	—

・Shearing Force (kN)

	Ultimate limit	Serviceability limit	
		permanent load	variable load
Ordinary	332.05	112.54	187.60
Wheel Load (Truck)	435.07	112.54	273.45
Earthquake	431.58	—	—

※The examination case of a fatigue limit state is only Wheel Load (Truck).

The section force of using by examination of a fatigue limit state is the same as the section force of using by examination of a serviceability limit state.

(ii) The parallel direction beam to the face line

・Bending Morment (kN・m)

	Ultimate limit		Serviceability limit			
	upper side	lower side	permanent load		variable load	
			upper	lower	side	side
Ordinary	93.82	46.91	33.48	15.95	48.95	24.49
Wheel Load (Truck)	193.48	117.85	33.48	15.95	131.97	86.55
Earthquake	746.93	633.97	—	—	—	—

・Shearing Force (kN)

	Ultimate limit	Serviceability limit	
		permanent load	variable load
Ordinary	159.97	56.03	82.78
Wheel Load (Truck)	303.30	56.03	202.21
Earthquake	399.69	—	—

※The examination case of a fatigue limit state is only Wheel Load (Truck).

The section force of using by examination of a fatigue limit state is the same as the section force of using by examination of a serviceability limit state.

		Prepared by Y. Ando		Checked by R. NISHIMURA	
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References/ Notes

(iii) Cantilever of a land side

Only examination of the steel reinforcement which tensile stress generates is performed.

・Bending Morment (kN・m)

	Ultimate limit		Serviceability limit			
	upper side	lower side	permanent load		variable load	
			upper	lower	upper	lower
Ordinary	—	—	—	—	—	—
Wheel Load (Truck)	547.78	—	100.58	—	364.29	—
Earthquake	—	—	—	—	—	—

・Shearing Force (kN)

	Ultimate limit	Serviceability limit	
		permanent load	variable load
Ordinary	—	—	—
Wheel Load (Truck)	392.74	92.10	242.86
Earthquake	—	—	—

※The examination case of a fatigue limit state is only Wheel Load (Truck).

The section force of using by examination of a fatigue limit state is the same as the section force of using by examination of a serviceability limit state.

6) Calculation of Reinforcing Bar Arrangement

References/ Notes

Calculation of reinforcing bar arrangement is performed by RC section calculation program. (FORUM8 Co., Ltd)

(1) Examination of Ultimate Limit State

a) Examination of Bending Strength

The area of reinforcing bar to be used calculates it as satisfying the following conditions.

$\gamma_i \cdot M_d \,/\, M_{ud} \leqq 1.0$

M_d ; calculated value of bending moment acting on pile in design

M_{ud} ; design bending moment capacity、It computes by the following formula.

$$M_{ud} = \frac{C'_c(d - y_c) + C'_s(d - d')}{\gamma_b} = \{A_s f_{yd} d - A'_s f_{yd} d' - \frac{(A_s f_{yd} - A'_s f_{yd})^2}{1.7 f'_{cd} b}\} / \gamma_b$$

C'_c ; The compression resultant of concrete (N) $(=0.68 \cdot f'_{cd} \cdot b \cdot x)$

C'_s ; Compressive force of acting on a compression reinforcing bar (N) $(=A'_s \cdot f'_{yd})$

T ; tensile force of a tensile reinforcing bar (N) $(=A_s \cdot f_{yd})$

As ; area of reinforcing bar in tensile zone (mm^2)

A's ; area of reinforcing bar in compressive zone (mm^2)

d ; effective depth of a tensile reinforcing bar (mm)

d' ; effective depth of a compressive reinforcing bar (mm)

x ; distance of a compression end and a neutral axis (mm)

y_c ; $=0.4 \cdot x$ (mm)

f_{yd} ; design tensile yield strength of steel (N/mm^2)

$(=f_{yk}/\gamma_{ms}=345\ N/mm^2)$

f_{yk} ; tensile yield strength of steel $(=345\ N/mm^2)$

γ_{ms} ; material factor of steel (=1.0)

f'_{cd} ; design compressive strength of concrete (N/mm^2)

$(=f'_{ck}/\gamma_{mc}=18.5\ N/mm^2)$

f'_{ck} ; characteristic compressive strength of concrete

$(=24\ N/mm^2)$

γ_{mc} ; material factor of concrete (=1.3)

γ_b ; member factor of bending members

γ_i ; structure factor

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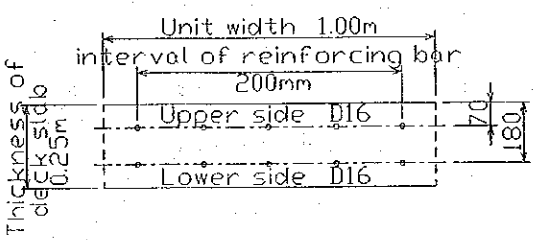
(i) Deck Slab

①Deck Slab "S1" : the parallel direction to the face line

・Examination of bending moment capacity of ultimate limit state

		unit	Ordinary		Wheel Load (Distribution)		Wheel Load (Partial distribution)	
			upper	lower	upper	lower	upper	lower
reinforcing bar (tension side)		mm	D16	D16	D16	D16	D16	D16
reinforcing bar (compression side)		mm	D16	D16	D16	D16	D16	D16
number (tension)			5	5	5	5	5	5
number (compression)			5	5	5	5	5	5
area of reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
area of reinforcement (compression)	A'_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
width of member	b_w	mm	1,000	1,000	1,000	1,000	1,000	1,000
effective depth (tension)	d	mm	180	180	180	180	180	180
effective depth (compression)	d	mm	180	180	180	180	180	180
f_{yd}	f_{yd}	N/mm^2	345	345	345	345	345	345
f'_{cd}	f'_{cd}	N/mm^2	18.5	18.5	18.5	18.5	18.5	18.5
M_{ud}		kN·m	59.80	59.80	59.80	59.80	59.80	59.80
M_d		kN·m	31.05	15.25	31.12	15.29	29.60	26.19
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.623	0.306	0.624	0.307	0.594	0.526
Judgment			O.K	O.K	O.K	O.K	O.K	O.K

・Dimension of an examination section



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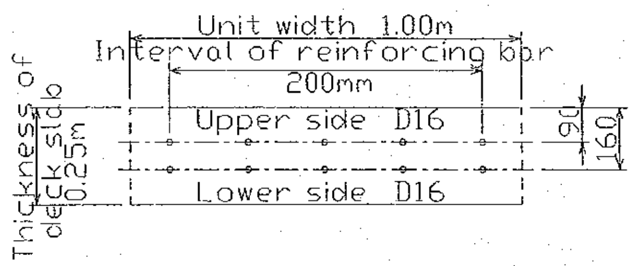
References/ Notes

②Deck Slab "S1" : the vertical direction to the face line

・Examination of bending moment capacity of ultimate limit state

		unit	Ordinary		Wheel Load (Distribution)		Wheel Load (Partial distribution)	
			upper	lower	upper	lower	upper	lower
reinforcing bar (tension side)		mm	D16	D16	D16	D16	D16	D16
reinforcing bar (compression side)		mm	D16	D16	D16	D16	D16	D16
number (tension)			5	5	5	5	5	5
number (compression)			5	5	5	5	5	5
area of reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
area of reinforcement (compression)	A'_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
width of member	b_w	mm	1,000	1,000	1,000	1,000	1,000	1,000
effective depth (tension)	d	mm	160	160	160	160	160	160
effective depth (compression)	d	mm	160	160	160	160	160	160
f_{yd}	f_{yd}	N/mm^2	345	345	345	345	345	345
f'_{cd}	f'_{cd}	N/mm^2	24	24	24	24	24	24
M_{ud}		kN·m	61.11	61.11	61.11	61.11	61.11	61.11
M_d		kN·m	21.37	3.93	21.42	3.94	25.87	22.11
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.420	0.077	0.421	0.077	0.508	0.434
Judgment			O.K	O.K	O.K	O.K	O.K	O.K

・Dimension of an examination section



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References/ Notes

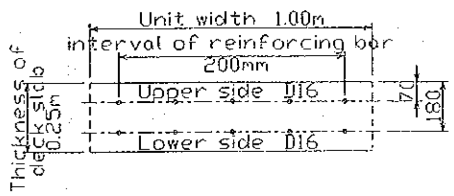
③Deck Slab "S3"

・Examination of bending moment capacity of ultimate limit state

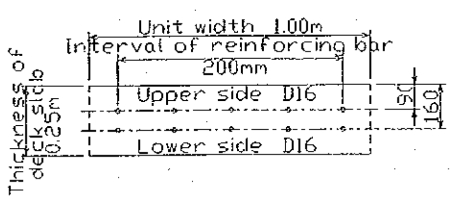
		unit	Ordinary Parallel		Ordinary Vertical	
			upper	lower	upper	lower
reinforcing bar (tension side)		mm	D16	D16	D16	D16
reinforcing bar (compression side)		mm	D16	D16	D16	D16
number (tension)		本	5	5	5	5
number (compression)		本	5	5	5	5
area of reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93
area of reinforcement (compression)	A'_s	cm^2	9.93	9.93	9.93	9.93
width of member	b_w	mm	1,000	1,000	1,000	1,000
effective depth (tension)	d	mm	180	180	160	160
effective depth (compression)	d	mm	180	180	160	160
f_{yd}	f_{yd}	N/mm^2	345	345	345	345
f'_{cd}	f'_{cd}	N/mm^2	24	24	24	24
M_{ud}		kN・m	59.80	59.80	61.11	61.11
M_d		kN・m	26.30	—	10.30	1.41
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.528	—	0.202	0.028
Judgment			O.K	—	O.K	O.K

・Dimension of an examination section

The parallel direction to the face line



The vertical direction to the face line



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References/ Notes

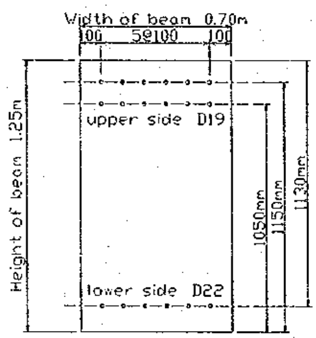
(ii) Beam

①The vertical direction beam to the face line

・Examination of bending moment capacity of ultimate limit state

		unit	Ordinary		Wheel Load		Wheel Load (Cantilever)		Earthquake	
			upper	lower	upper	lower	upper	lower	upper	lower
reinforcing bar (tension side)		mm	D19	D22	D19	D22	D19	D22	D19	D22
reinforcing bar (compression side)		mm	D22	D19	D22	D19	D22	D19	D22	D19
number (tension)			12	6	12	6	12	6	12	6
number (compression)			6	12	6	12	6	12	6	12
area of reinforcement (tension)	A_s	cm^2	34.38	23.23	34.38	23.23	34.38	23.23	34.38	23.23
area of reinforcement (compression)	A'_s	cm^2	23.23	34.38	23.23	34.38	23.23	34.38	23.23	34.38
width of member	b_w	mm	700	700	700	700	700	700	700	700
effective depth (tension)	d	mm	1,100	1,130	1,100	1,130	1,100	1,130	1,100	1,130
effective depth (compression)	d	mm	1,130	1,100	1,130	1,100	1,130	1,100	1,130	1,100
f_{yd}	f_{yd}	N/mm^2	345	345	345	345	345	345	345	345
f'_{cd}	f'_{cd}	N/mm^2	24	24	24	24	24	24	24	24
M_{ud}		kN・m	1,081.7	815.52	1,076.5	815.52	1,076.5	815.52	1,076.5	815.52
M_d		kN・m	310.49	180.92	332.87	341.77	547.78	—	938.95	661.57
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.344	0.266	0.371	0.503	0.611	—	0.872	0.811
Judgment			O.K	O.K	O.K	O.K	O.K	—	O.K	O.K

・Dimension of an examination sectio



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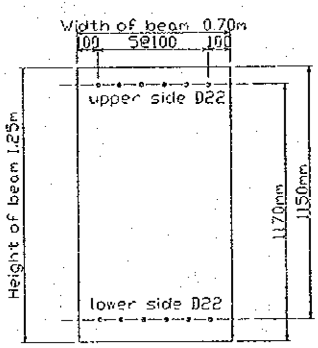
References/ Notes

②The parallel direction beam to the face line

・Examination of bending moment capacity of ultimate limit state

		unit	Ordinary		Wheel Load		Earthquake	
			upper	lower	upper	lower	upper	lower
reinforcing bar (tension side)		mm	D22	D22	D22	D22	D22	D22
reinforcing bar (compression side)		mm	D22	D22	D22	D22	D22	D22
number (tension)			6	6	6	6	6	6
number (compression)			6	6	6	6	6	6
area of reinforcement (tension)	A_s	cm^2	23.23	23.23	23.23	23.23	23.23	23.23
area of reinforcement (compression)	A'_s	cm^2	23.23	23.23	23.23	23.23	23.23	23.23
width of member	b_w	mm	700	700	700	700	700	700
effective depth (tension)	d	mm	1,170	1,150	1,170	1,150	1,170	1,150
effective depth (compression)	d	mm	1,150	1,170	1,150	1,170	1,150	1,170
f_{yd}	f_{yd}	N/mm^2	345	345	345	345	345	345
f'_{cd}	f_{cd}	N/mm^2	24	24	24	24	24	24
M_{ud}		kN・m	790.26	774.70	790.26	774.70	790.26	774.70
M_d		kN・m	93.82	46.91	193.48	117.85	746.93	633.97
Examination result ($\gamma_i \cdot M_d / M_{ud}$)			0.142	0.073	0.294	0.183	0.945	0.818
Judgment			O.K	O.K	O.K	O.K	O.K	O.K

・Dimension of an examination section



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b) Examination of the Shearing Force

The steel reinforcement to be used calculates it as satisfying the following conditions.

$\gamma_i \cdot V_d / V_{yd} \leqq 1.0$

$V_{yd} = V_{cd} + V_{sd}$

V_{yd} ; design shear capacity

V_{cd} ; design shear capacity without shear reinforcement. It computes by the following formulas.

$V_{cd} = \beta_d \cdot \beta_p \cdot \beta_n \cdot f_{vcd} \cdot b_w \cdot d / \gamma_b$

f_{vcd} ; $0.2\times(f'_{cd})^{1/3}$

β_d ; coefficient to consider influence of effective depth on shear capacity

$\beta_d=(1000/d)^{1/4}$

β_p ; coefficient to consider influence of longitudinal reinforcement on shear capacity

$\beta_p=(100\cdot p_w)^{1/3}$

β_n ; coefficient to consider influence of axial force on shear capacity

$\beta_n=1+M_0/M_d$ $(N'_d\geqq 0)$ when $\beta_n>2$, β_n is taken as 2.0

$\beta_n=1+2M_0/M_d$ $(N'_d<0)$ when $\beta_n<0$, β_n is taken as 0.0

N'_d ; design axial compressive force (N)

M_d ; design bending moment (N·mm)

M_0 ; decompression moment necessary to cancel the fiber stress due to axial force at the tension fiber corresponding to design moment M_d

b_w ; web width (mm)

d ; effective depth (mm)

p_w ; balanced ratio of reinforcement$=A_s/(b_w\cdot d)$

A_s ; area of reinforcing bar (mm^2)

f'_{cd} ; design compressive strength of concrete (=18.5N/mm^2)

γ_b ; member factor (=1.30)

V_{sd} ; design shear capacity carried by shear reinforcing steel

$$V_{sd} = \frac{A_w \cdot f_{wyd}}{S_s}(\sin\alpha_s + \cos\alpha_s)\cdot z/\gamma_b$$

A_w ; total amount of area of shear reinforcement over the interval S_s (mm^2)

f_{wyd} ; design yield strength of shear reinforcement (=345 N/mm^2)

α_s ; angle between shear reinforcement and member axis

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S_s ; spacing of shear reinforcement (mm)

z ; distance from compression resultant to centroid of tension steel

Generally , d/1.15

γ_b ; member factor

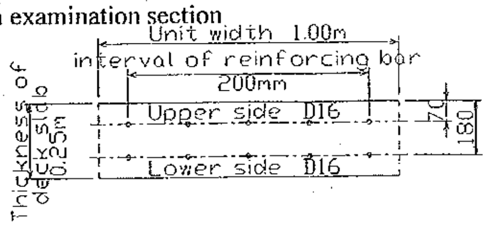
(i) Deck Slab

①Deck Slab "S1" : the parallel direction to the face line

・Examination of shearing force capacity of ultimate limit state

		unit	Ordinary	Wheel Load (Distribution)	Wheel Load (Partial distribution)
reinforcing bar		mm	D16	D16	D16
number			5	5	5
area of reinforcing bar	A_s	cm^2	9.93	9.93	9.93
web width	b_w	mm	1,000	1,000	1,000
effective depth	d	mm	180	180	180
axial compressive force	N'_d	kN	0	0	0
A_w	A_w	mm^2	2.534	2.534	2.534
α_s	α_s	°	90	90	90
S_s	S_s	mm	200	200	200
V_{cd}		kN	90.02	90.02	90.02
V_{sd}		kN	59.49	59.49	59.49
V_{yd}		kN	149.51	149.51	149.51
V_d		kN	49.48	49.60	50.34
Examination result ($\gamma_i \cdot V_d / V_{yd}$)			0.397	0.398	0.404
Judgment			O.K	O.K	O.K

・Dimension of an examination section



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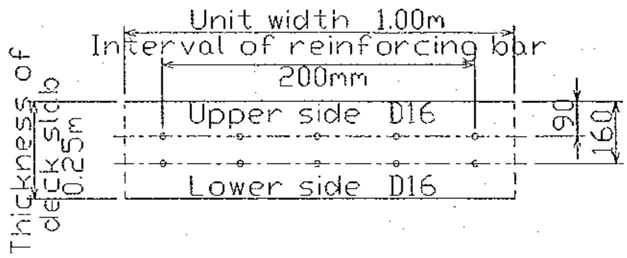
②Deck Slab "S1" : the vertical direction to the face line

・Examination of shearing force capacity of ultimate limit state

		unit	Ordinary	Wheel Load (Distribution)	Wheel Load (Partial distribution)
reinforcing bar		mm	D16	D16	D16
number			5	5	5
area of reinforcing bar	A_s	cm^2	9.93	9.93	9.93
web width	b_w	mm	1,000	1,000	1,000
effective depth	d	mm	160	160	160
axial compressive force	N'_d	kN	0	0	0
A_w	A_w	mm^2	2.534	2.534	2.534
α_s	α_s	°	90	90	90
S_s	S_s	mm	200	200	200
V_{cd}		kN	83.24	83.24	83.24
V_{sd}		kN	52.88	52.88	52.88
V_{yd}		kN	136.12	136.12	136.12
V_d		kN	55.37	55.51	41.57
Examination result ($\gamma_i \cdot V_d / V_{yd}$)			0.488	0.489	0.366
Judgment			O.K	O.K	O.K

・Dimension of an examination section



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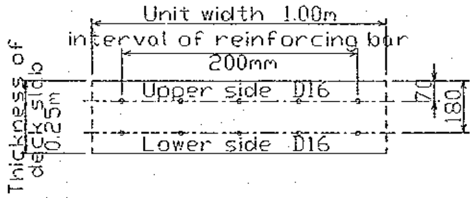
③Deck Slab "S3"

・Examination of shearing force capacity of ultimate limit state

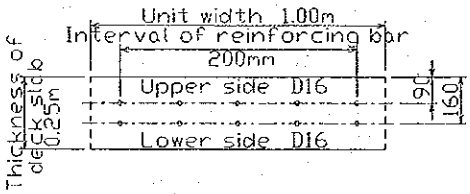
		unit	Ordinary Parallel	Ordinary Vertical
reinforcing bar		mm	D16	D16
number			5	5
area of reinforcing bar	A_s	cm^2	9.93	9.93
web width	b_w	mm	1,000	1,000
effective depth	d	mm	180	160
axial compressive force	N'_d	kN	0	0
A_w	A_w	mm^2	2.534	2.534
α_s	α_s	°	90	90
S_s	S_s	mm	200	200
V_{cd}		kN	90.02	83.24
V_{sd}		kN	59.49	52.88
V_{yd}		kN	149.51	136.12
V_d		kN	46.82	61.51
Examination result $(\gamma_i \cdot V_d / V_{yd})$			0.376	0.542
Judgment			O.K	O.K

・Dimension of an examination section

The parallel direction to the face line



The vertical direction to the face line



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References/ Notes

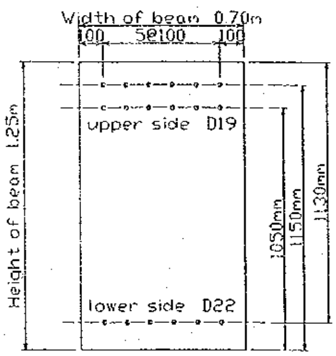
(ii) Beam

①The vertical direction beam to the face line

・Examination of shearing force capacity of ultimate limit state

		unit	Ordinary	Wheel Load	Wheel Load (Cantilever)	Earthquake
reinforcing bar		mm	D22	D22	D22	D22
number			6	6	6	6
area of reinforcing bar	A_s	cm^2	23.23	23.23	23.23	23.23
web width	b_w	mm	700	700	700	700
effective depth	d	mm	1,130	1,130	1,130	1,130
axial compressive force	N'_d	kN	0	0	0	0
A_w	A_w	mm^2	2.534	2.534	2.534	2.534
α_s	α_s	°	90	90	90	90
S_s	S_s	mm	100	100	100	100
V_{cd}		kN	207.47	207.47	207.47	207.47
V_{sd}		kN	746.98	746.98	746.98	746.98
V_{yd}		kN	954.45	954.45	954.45	954.45
V_d		kN	332.05	435.07	392.74	431.58
Examination result ($\gamma_i \cdot V_d / V_{yd}$)			0.417	0.547	0.494	0.452
Judgment			O.K	O.K	O.K	O.K

・Dimension of an examination section



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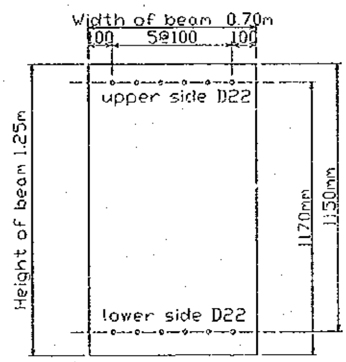
References/ Notes

②The parallel direction beam to the face line

• Examination of shearing force capacity of ultimate limit state

		unit	Ordinary	Wheel Load	Earthquake
reinforcing bar		mm	D22	D22	D22
number			6	6	6
area of reinforcing bar	A_s	cm^2	23.23	23.23	23.23
web width	b_w	mm	700	700	700
effective depth	d	mm	1,150	1,150	1,150
axial compressive force	N'_d	kN	0	0	0
A_w	A_w	mm^2	2.534	2.534	2.534
α_s	α_s	°	90	90	90
S_s	S_s	mm	100	100	100
V_{cd}		kN	209.01	209.01	209.01
V_{sd}		kN	760.20	760.20	760.20
V_{yd}		kN	969.21	969.21	969.21
V_d		kN	159.97	303.30	399.69
Examination result $(\gamma_i \cdot V_d / V_{yd})$			0.198	0.376	0.412
Judgment			O.K	O.K	O.K

• Dimension of an examination section



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(2) Examination of Serviceability Limit State

Design load is computed using the following formulas.

$S_k = k_p \times S_p + k_r \times S_r$

where

S_k : characteristic value of load for examination of the serviceability limit state

S_p : characteristic value of permanent load

S_r : characteristic value of variable load

k_p, k_r : constans to represent the effects on crake widths and the corrosion of steel by the permanent load and variable load, respectively. It may be taken that k_p is 1.0 and k_r is 0.5.

a) Examination of Flexural Cracks

Flexural crack width (w (mm)) is computed by the following formulas.

$$w = k \cdot \{4c + 0.7(Cs - \phi)\} \cdot \left(\frac{\sigma_{se}}{Es} + \varepsilon'_{csd}\right)$$

k ; constant indicating the effect of the bonding properties of the steel material, which may usually be taken as 1.0 in the case of deformed bars.

c ; covering(mm)

Cs ; distance between centers of steel materials(mm)

ϕ ; diameter of steel materials(mm)

ε'_{csd} ; constant introduced to represent the increase of crack width caused by creep and drying shrinkage of concrete (this can be o under seaweter, and elsewhere 150×10^{-6})

σ_{se} ; increased stress on reinforcement $(=M_e/(A_s\, j\, d))$

Es ; Young's modulus of reinforcement $(=2.00 \times 10^5\ N/mm^2)$

M_e ; bending moment

A_s ; area of reinforcing bar (mm^2)

j ; Distance between stress (mm)

d ; effective depth (mm)

Permisible crake width is computed by the following formulas.

- Permisible crake width upper side reinforcing bar w_a=0.0040 c (mm)
  lower side reinforcing bar w_a=0.0035 c (mm)

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References/ Notes

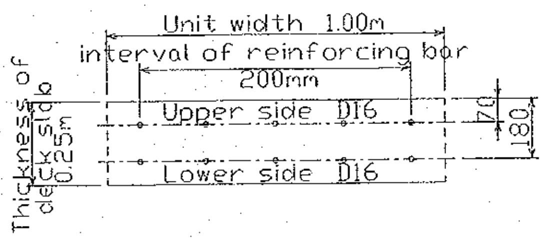
(i) Deck Slab

①Deck Slab "S1" : the parallel direction to the face line

・Examination of flexural crack of serviceability state

		unit	Ordinary		Wheel Load (Distribution)		Wheel Load (Partial distribution)	
			upper	lower	upper	lower	upper	lower
reinforcing bar		mm	D16	D16	D16	D16	D16	D16
diameter	ϕ	mm	16	16	16	16	16	16
covering	c	mm	60	70	60	70	60	70
distance between centers of bar	C_s	mm	200	200	200	200	200	200
moment (permanent load)	M_e	kN·m	6.09	2.99	6.09	2.99	6.09	2.99
moment (variable load)	M_e	kN·m	20.29	9.97	20.35	10.00	19.08	19.08
moment (design load)	M_e	kN·m	16.24	7.98	16.27	7.99	15.63	12.53
reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
effective depth	d	mm	180	180	180	180	180	180
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	94.95	46.64	95.13	46.73	91.41	73.28
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	35.62	17.49	35.62	17.49	35.62	17.49
flexural crack width (design load)	w1	mm	0.230	0.141	0.231	0.141	0.224	0.190
flexural crack width (permanent load)	w2	mm	0.121	0.088	0.121	0.088	0.121	0.088
permisible crake width	w_a	mm	0.240	0.210	0.240	0.210	0.240	0.210
Examination result (design load)			$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K
Examination result (permanent load)			$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K

・Dimension of an examination section



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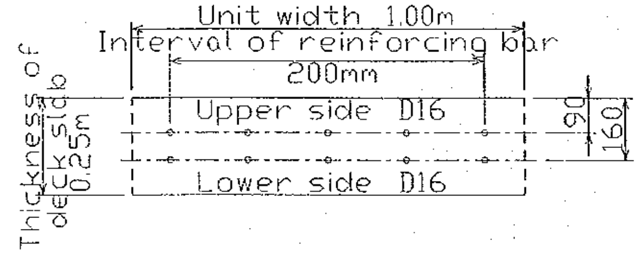
References/ Notes

②Deck Slab "S1" : the vertical direction to the face line

· Examination of flexural crack of serviceability state

		unit	Ordinary		Wheel Load (Distribution)		Wheel Load (Partial distribution)	
			upper	lower	upper	lower	upper	lower
reinforcing bar		mm	D16	D16	D16	D16	D16	D16
diameter	ϕ	mm	16	16	16	16	16	16
covering	c	mm	80	90	80	90	80	90
distance between centers of bar	C_s	mm	200	200	200	200	200	200
moment (permanent load)	M_e	kN·m	4.19	0.77	4.19	0.77	4.19	0.77
moment (variable load)	M_e	kN·m	13.97	2.57	14.01	2.58	17.72	17.72
moment (design load)	M_e	kN·m	11.18	2.06	11.20	2.06	13.05	9.63
reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93	9.93	9.93
effective depth	d	mm	160	160	160	160	160	160
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	65.90	12.12	66.02	12.15	76.95	56.79
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	24.71	4.54	24.71	4.54	24.71	4.54
flexural crack width (design load)	w1	mm	0.215	0.095	0.215	0.095	0.240	0.195
flexural crack width (permanent load)	w2	mm	0.123	0.078	0.123	0.078	0.123	0.078
permisible crake width	w_a	mm	0.320	0.280	0.320	0.280	0.320	0.280
Examination result (design load)			$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K
Examination result (permanent load)			$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K

· Dimension of an examination section



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References/ Notes

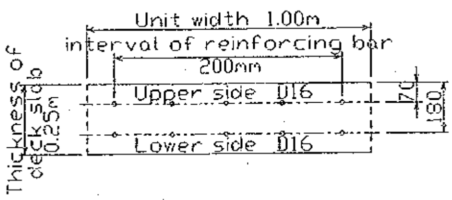
③Deck Slab "S3"

・Examination of flexural crack of serviceability state

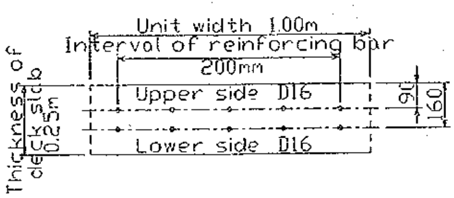
		unit	Ordinary Parallel		Ordinary Vertical	
			upper	lower	upper	lower
reinforcing bar		mm	D16	D16	D16	D16
diameter	ϕ	mm	16	16	16	16
covering	c	mm	60	70	80	90
distance between centers of bar	C_s	mm	200	200	200	200
moment (permanent load)	M_e	kN·m	5.16	—	2.02	0.28
moment (variable load)	M_e	kN·m	17.19	—	6.73	0.92
moment (design load)	M_e	kN·m	13.76	—	5.39	0.74
reinforcement (tension)	A_s	cm^2	9.93	9.93	9.93	9.93
effective depth	d	mm	180	180	160	160
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	80.45	—	31.75	4.36
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	30.18	—	11.91	1.65
flexural crack width (design load)	w1	mm	0.204	—	0.139	0.077
flexural crack width (permanent load)	w2	mm	0.111	—	0.094	0.071
permisible crake width	w_a	mm	0.240	—	0.320	0.280
Examination result (design load)			$w1<w_a$ O.K	—	$w1<w_a$ O.K	$w1<w_a$ O.K
Examination result (permanent load)			$w2<w_a$ O.K	—	$w2<w_a$ O.K	$w2<w_a$ O.K

・Dimension of an examination section

The parallel direction to the face line



The vertical direction to the face line



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References/ Notes

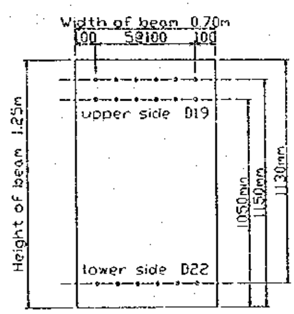
(ii) Beam

①The vertical direction beam to the face line

・Examination of flexural crack of serviceability state

		unit	Ordinary		Wheel Load		Wheel Load (Cantilever)	
			upper	lower	upper	lower	upper	lower
reinforcing bar		mm	D19	D22	D19	D22	D19	D22
diameter	ϕ	mm	19	22	19	22	19	22
covering	c	mm	80	90	80	90	80	90
distance between centers of bar	C_s	mm	100	100	100	100	100	100
moment (permanent load)	M_e	kN·m	150.80	52.43	150.80	52.43	100.58	—
moment (variable load)	M_e	kN·m	174.50	116.08	201.25	252.45	364.29	—
moment (design load)	M_e	kN·m	238.05	110.47	251.43	178.66	282.73	—
reinforcement (tension)	A_s	cm^2	34.38	23.23	34.38	23.23	34.38	23.23
effective depth	d	mm	1,100	1,130	1,100	1,130	1,100	1,130
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	71.33	45.03	76.11	72.83	85.58	—
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	45.19	21.37	45.65	21.37	30.45	—
flexural crack width (design load)	w1	mm	0.211	0.186	0.221	0.254	0.240	—
flexural crack width (permanent load)	w2	mm	0.157	0.127	0.158	0.127	0.125	—
permisible crake width	w_a	mm	0.360	0.350	0.360	0.350	0.360	0.350
Examination result (design load)			$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K
Examination result (permanent load)			$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K

・Dimension of an examination section



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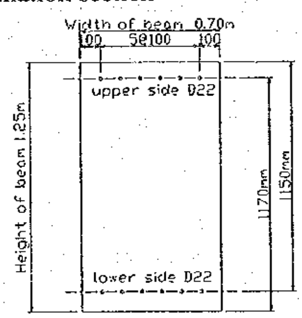
References/ Notes

②The parallel direction beam to the face line

• Examination of flexural crack of serviceability state

		unit	Ordinary		Wheel Load	
			upper	lower	upper	lower
reinforcing bar		mm	D22	D22	D22	D22
diameter	ϕ	mm	22	22	22	22
covering	c	mm	60	70	60	70
distance between centers of bar	C_s	mm	100	100	100	100
moment (permanent load)	M_e	kN·m	33.48	15.95	33.48	15.95
moment (variable load)	M_e	kN·m	48.95	24.49	131.97	86.55
moment (design load)	M_e	kN·m	57.96	28.20	99.47	59.23
reinforcement (tension)	A_s	cm^2	23.23	23.23	23.23	23.23
effective depth	d	mm	1,150	1,170	1,150	1,170
increased stress on reinforcement (design load)	σ_{se}	N/mm^2	22.77	11.25	39.08	23.63
increased stress on reinforcement (permanent load)	σ_{se}	N/mm^2	13.15	6.36	13.15	6.36
flexural crack width (design load)	w1	mm	0.088	0.086	0.116	0.111
flexural crack width (permanent load)	w2	mm	0.072	0.075	0.072	0.075
permisible crake width	w_a	mm	0.280	0.315	0.280	0.315
Examination result (design load)			$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K	$w1<w_a$ O.K
Examination result (permanent load)			$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K	$w2<w_a$ O.K

• Dimension of an examination section



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b) Examination of Shear Cracks

For members subject to shear forces, it may not be required to examine shear cracks when the design shear force, Vd, is smaller than 70% of the design shear capacity of concrete, Vcd. When examination for shear crack is necessary, the stress in shear reinforcement due to permanent load is confirmed smaller than the limiting value for the increment in stress in ordinary reinforcement due to permanent load.

$$\sigma wpd = \frac{(Vpd + Vrd - k_2 \times Vcd) \times s}{Aw \times z \times (\sin \alpha s + \cos \alpha s)} \times \frac{Vpd + Vcd}{Vpd + Vrd + Vcd}$$

wher 、 σ wpd : design stress in shear reinforcement due to permanent load

Vpd : design shear force produced by permanent load

Vrd : design shear force produced by variable load

Vcd : design shear capacity of concrete

(see examination of shearing force of ultimate limit state

It considers as $\gamma b = \gamma c = 1.0$)

Aw : area of one unit of shear reinforcement

s : spacing of shear reinforcement

z : distance from compression resultant to centroid of tension reinforcement (=d/1.15)

d : effective depth

α s : angle between shear reinforcement and axis of member

k_2 : The factor for taking into consideration the influence of the frequency of change load (=0.5)

The limiting value for the increment in stress in ordinary reinforcement due to permanent load " σ sp" uses the following values. (see "Standard Specifications of Concrete (in Japan))

When a upper side reinforcing bar steel rod is examined $\sigma sp = 100$ N/mm^2

When a lower side reinforcing bar steel rod is examined $\sigma sp = 80$ N/mm^2

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References/ Notes

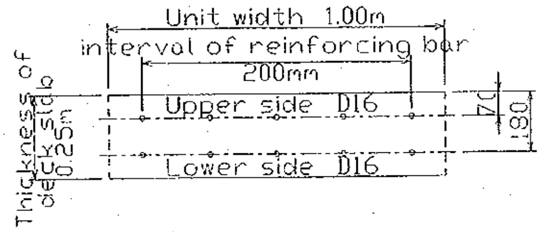
(i) Deck Slab

①Deck Slab "S1" : the parallel direction to the face line

・Examination of shear crack

		unit	Ordinary	Wheel Load (Distribution)	Wheel Load (Partial distribution)
reinforcing bar		mm	D16	D16	D16
number			5	5	5
area of tension reinforcing bar	A_s	cm^2	9.93	9.93	9.93
web width	b_w	mm	1,000	1,000	1,000
effective depth	d	mm	180	180	180
compression force of an axis	N'_d	kN	0	0	0
design shear capacity of concrete	V_{cd}	kN	127.73	127.73	127.73
design shear force	V_d	kN	25.87	25.92	26.23
Examination result (V_d/V_{cd})			0.203	0.203	0.205
Necessity for examination of shear crack			without necessity	without necessity	without necessity
σ wpd			—	—	—
σ sp			—	—	—
Judgment			—	—	—

・Dimension of an examination section



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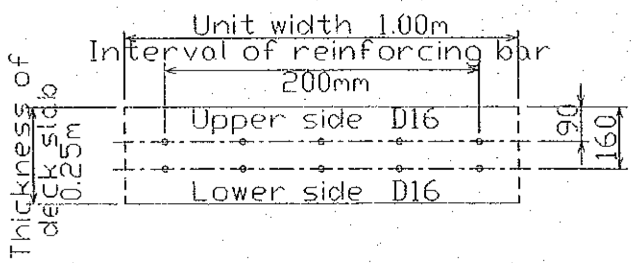
References/ Notes

②Deck Slab "S1" : the vertical direction to the face line

・Examination of shear crack

		unit	Ordinary	Wheel Load (Distribution)	Wheel Load (Partial distribution)
reinforcing bar		mm	D16	D16	D16
number		本	5	5	5
area of tension reinforcing bar	A_s	cm^2	9.93	9.93	9.93
web width	b_w	mm	1,000	1,000	1,000
effective depth	d	mm	160	160	160
compression force of an axis	N'_d	kN	0	0	0
design shear capacity of concrete	V_{cd}	kN	118.10	118.10	118.10
design shear force	V_d	kN	28.96	29.01	23.21
Examination result (V_d/V_{cd})			0.245	0.246	0.196
Necessity for examination of shear crack			without necessity	without necessity	without necessity
σ wpd			—	—	—
σ sp			—	—	—
Judgment			—	—	—

・Dimension of an examination section



		Prepared by Y.Ando		Checked by R. NISHIMURA
			26/07/2002	08/08/2002

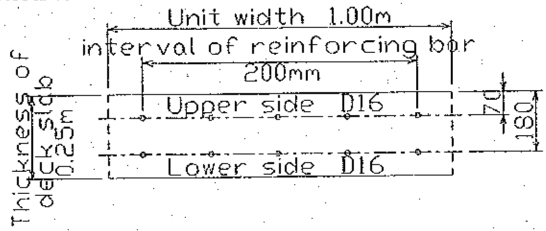
③Deck Slab "S3"

・Examination of shear crack

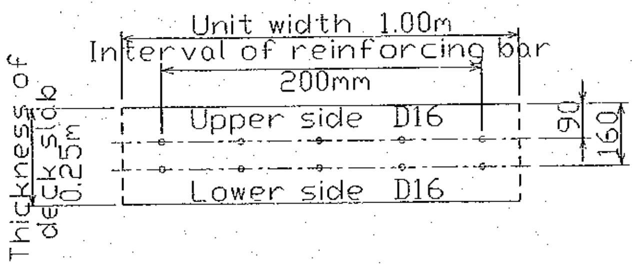
		単位	Ordinary Parallel	Ordinary Vertical
reinforcing bar		mm	D16	D16
number		本	5	5
area of tension reinforcing bar	A_s	cm^2	9.93	9.93
web width	b_w	mm	1,000	1,000
effective depth	d	mm	180	160
compression force of an axis	N'_d	kN	0	0
design shear capacity of concrete	V_{cd}	kN	127.73	118.10
design shear force	V_d	kN	24.48	32.16
Examination result (V_d/V_{cd})			0.192	0.272
Necessity for examination of shear crack			without necessity	without necessity
σ wpd			—	—
σ sp			—	—
Judgment			—	—

・Dimension of an examination section

The parallel direction to the face line



The vertical direction to the face line



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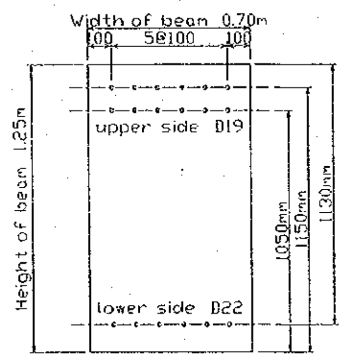
(ii) Beam

①The vertical direction beam to the face line

・Examination of shear crack

		単位	Ordinary	Wheel Load	Wheel Load (Cantilever)
reinforcing bar		mm	D22	D22	D22
number		本	6	6	6
area of tension reinforcing bar	A_s	cm^2	23.23	23.23	23.23
web width	b_w	mm	700	700	700
effective depth	d	mm	1,130	1,130	1,130
compression force of an axis	N'_d	kN	0	0	0
design shear capacity of concrete	V_{cd}	kN	294.35	294.35	294.35
design shear force	V_d	kN	206.34	249.27	213.53
Examination result (V_d/V_{cd})			0.701	0.847	0.725
Necessity for examination of shear crack			with necessity	with necessity	with necessity
σ wpd			42.05	57.36	46.31
σ sp			80.00	80.00	80.00
Judgment			O.K	O.K	O.K

・Dimension of an examination section



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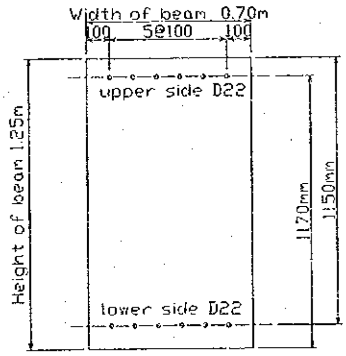
②The parallel direction beam to the face line

・Examination of shear crack

		unit	Ordinary	Wheel Load
reinforcing bar		mm	D22	D22
number		本	6	6
area of tension reinforcing bar	A_s	cm^2	23.23	23.23
web width	b_w	mm	700	700
effective depth	d	mm	1,150	1,150
compression force of an axis	N'_d	kN	0	0
design shear capacity of concrete	V_{cd}	kN	296.53	296.53
design shear force	V_d	kN	97.42	157.14
Examination result (V_d/V_{cd})			0.329	0.530
Necessity for examination of shear crack			without necessity	without necessity
σ wpd			—	—
σ sp			—	—
Judgment			—	—

・Dimension of an examination section



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(3) Examination to Fatigue Limit State

An examination case is set to Wheel Load (Truck). The fatigue life (number of times of a wheel load action) is as follows.

The number of car loading per car carrier : 650

The number of times of car carriers entry into port per year : 33 times / year

Lifetime of Berth : 50 years

Fatigue Life $650 \times 33 \times 50 = 1{,}072{,}500$ times

The unloading of the car is equally carried out at platforms 1 and 2. Therefore, lifetime per platform becomes as follows.

$N = 1{,}072{,}500 / 2 = 536{,}250$ times → 540,000 times

a) Examination of Fatigue Limit of Bending

(i) Examination of reinforcing bar

The safety to the fatigue limit state of the reinforcing bar is checked by the following formulas.

$$\gamma i \times \sigma sed / (fsrd / \gamma b) \leqq 1.0$$

where

σ srd : stress in reinforcement due to variable load (N/mm^2)

γ i : structure factor

γ b : member factor

fsrd : design fatigue strength for a reinforcing bar

$$fsrd = 190 \times \frac{10^{\alpha}}{N^{k}} \times \left(1 - \frac{\sigma sp}{fud}\right) / \gamma s$$

$$\alpha = k_0 \times (0.81 - 0.003 \times \phi)$$

$$k = 0.12$$

φ : diameter of reinforcing bar (mm)

k_0 : factor concerning α (=1.0)

fud : design tensile strength of steel (N/mm^2) (=fuk / γ s)

=490 / 1.05 = 466.67 N/mm^2

fuk : characteristic value for tensile strength of steel (N/mm^2)

γ s : material factor for steel

σ sp : stress of a reinforcing bar due to permanent load (N/mm^2)

N : fatigue life

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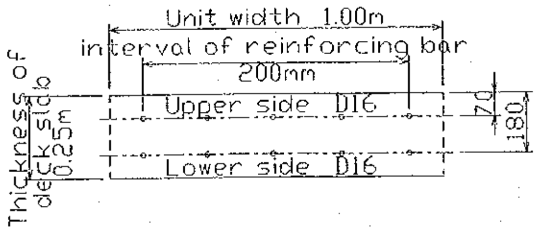
①Deck Slab

①— 1 Deck Slab "S1" : the parallel direction to the face line

○Examination of fatigue limit of bending of reinforcing bar (deck slab)

	unit	Wheel Load (Distribution)		Wheel Load (Partial distribution)	
		upper	lower	upper	lower
α		0.762	0.762	0.762	0.762
k		0.12	0.12	0.12	0.12
diameter "φ"	mm	16	16	16	16
k_0		1.0	1.0	1.0	1.0
design tensile strength of steel fud	N/mm^2	466.67	466.67	466.67	466.67
bending moment (permanent load) Mpd	kN・m	6.09	2.99	6.09	2.99
bending moment (variable load) Mrd	kN・m	20.35	10.00	19.08	19.08
σ sp	N/mm^2	35.62	17.49	35.62	17.49
fatigue life N	times	540,000	540,000	540,000	540,000
design fatigue strength for a reinforcing bar fsrd		198.24	206.58	198.24	206.58
stress in reinforcement due to variable load σ srd		119.02	58.49	111.59	111.59
Examination result γ i ・ σ srd / (fsrd / b)		0.60 O.K	0.28 O.K	0.56 O.K	0.54 O.K

・Dimension of an examination section



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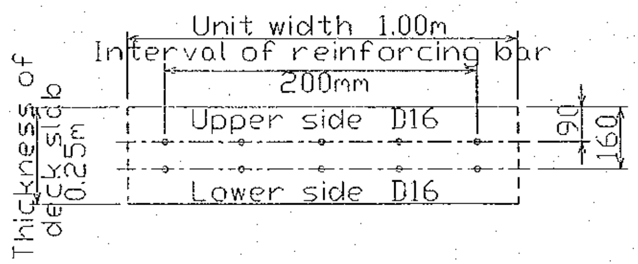
①－2 Deck Slab "S1" : the vertical direction to the face line

○Examination of fatigue limit of bending of reinforcing bar (deck slab)

	unit	Wheel Load (Distribution)		Wheel Load (Partial distribution)	
		upper	lower	upper	lower
α		0.762	0.762	0.762	0.762
k		0.12	0.12	0.12	0.12
diameter "ϕ"	mm	16	16	16	16
k_0		1.0	1.0	1.0	1.0
design tensile strength of steel fud	N/mm^2	466.67	466.67	466.67	466.67
bending moment (permanent load) Mpd	kN・m	4.19	0.77	4.19	0.77
bending moment (variable load) Mrd	kN・m	14.01	2.58	17.72	17.72
σ sp	N/mm^2	24.71	4.54	24.71	4.54
fatigue life N	times	540,000	540,000	540,000	540,000
design fatigue strength for a reinforcing bar fsrd		203.26	212.54	203.26	212.54
stress in reinforcement due to variable load σ srd		82.62	15.21	104.49	104.49
Examination result γi・σ srd / (fsrd / b)		0.41 O.K	0.07 O.K	0.51 O.K	0.49 O.K

・Dimension of an examination section



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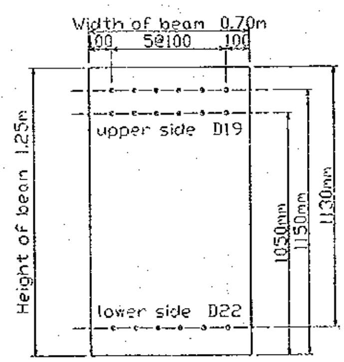
②Beam

○Examination of fatigue limit of bending of reinforcing bar (beam)

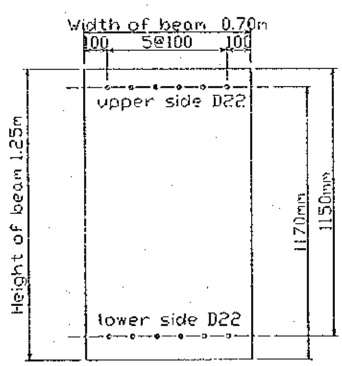
	unit	The vertical direction beam to the face line			The parallel direction beam to the face line	
		upper	lower	cantilever	upper	lower
α		0.753	0.744	0.753	0.744	0.744
k		0.12	0.12	0.12	0.12	0.12
diameter " ϕ "	mm	19	22	19	22	22
k_0		1.0	1.0	1.0	1.0	1.0
design tensile strength of steel fud	N/mm^2	466.67	466.67	466.67	466.67	466.67
bending moment (permanent load) Mpd	kN・m	150.80	52.43	100.58	33.48	15.95
bending moment (variable load) Mrd	kN・m	201.25	252.45	364.29	131.97	86.55
σ sp	N/mm^2	45.65	21.37	30.45	13.15	6.36
fatigue life N	times	540,000	540,000	540,000	540,000	540,000
design fatigue strength for a reinforcing bar fsrd		189.66	196.48	192.48	200.11	203.10
stress in reinforcement due to variable load σ srd		60.92	102.91	110.27	51.85	34.53
Examination result γ i・σ srd / (fsrd / b)		0.32 O.K	0.52 O.K	0.57 O.K	0.26 O.K	0.17 O.K

・Dimension of an examination section (Beam)

Vertical to the face line



Parallel to the face line



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References/ Notes

(ii) Examination of Concrete

The safety to the fatigue limit state of concrete is checked by the following formulas.

$\gamma i \times \sigma' ced / (frd / \gamma b) \leqq 1.0$

where

σ'crd : stress in concrete due to variable load (N/mm^2)

γ i : structure factor

γ b : member factor

frd : design fatigue strength for concrete (N/mm^2)

$$frd = k_1 \times fd \times \left(1 - \frac{\sigma p}{fd}\right) \times \left(1 - \frac{\log N}{K}\right)$$

$k_1 = 0.85$ 、 K=17

fd : design compressive strength of concrete (N/mm^2) (=f'ck / γ c)

$fd = 24 / 1.3 = 18.46\ N/mm^2$

f'ck : basic strength for design (= 24 N/mm^2)

γ c : material factor for concrete (=1.3)

σ p : stress of concrete due to permanent load (N/mm^2)

N : fatigue life

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①Deck Slab

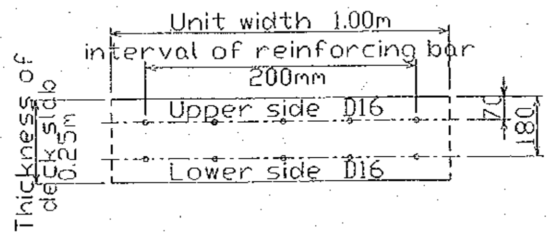
①－1 Deck Slab "S1" : the parallel direction to the face line

○Examination of fatigue limit of bending of concrete (deck slab)

	unit	Wheel Load (Distribution)		Wheel Load (Partial distribution)	
		upper	lower	upper	lower
design compressive strength of concrete fd	N/mm²	18.46	18.46	18.46	18.46
k1		0.85	0.85	0.85	0.85
K		17	17	17	17
stress of concrete due to permanent load σ p	N/mm²	1.25	0.62	1.25	0.62
fatigue life N	times	540,000	540,000	540,000	540,000
design compressive strength of concrete frd		9.69	10.05	9.69	10.05
stress in concrete due to variable load σ 'crd		4.19	2.06	3.92	3.93
Examination result γ i× σ 'crd / (frd / γ b)		0.43 O.K	0.20 O.K	0.40 O.K	0.39 O.K

※Section force is the same value as what was used by examination of reinforcing bar.

・Dimension of an examination section



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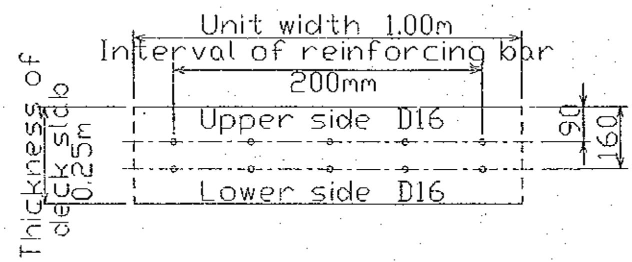
①− 2 Deck Slab "S1" : the vertical direction to the face line

○Examination of fatigue limit of bending of concrete (deck slab)

	unit	Wheel Load (Distribution)		Wheel Load (Partial distribution)	
		upper	lower	upper	lower
design compressive strength of concrete fd	N/mm²	18.46	18.46	18.46	18.46
k1		0.85	0.85	0.85	0.85
K		17	17	17	17
stress of concrete due to permanent load σ p	N/mm²	1.03	0.19	1.03	0.19
fatigue N	times	540,000	540,000	540,000	540,000
design compressive strength of concrete frd		9.82	10.29	9.82	10.29
stress in concrete due to variable load σ 'crd		3.43	0.63	4.34	4.34
Examination result γ i× σ 'crd / (frd / γ b)		0.35 O.K	0.07 O.K	0.44 O.K	0.42 O.K

※Section force is the same value as what was used by examination of reinforcing bar.

・Dimension of an examination section



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References/ Notes

②Beam

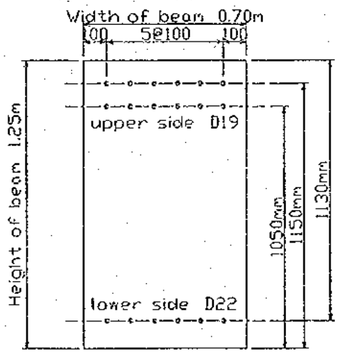
○Examination of fatigue limit of bending of concrete (beam)

	unit	Wheel Load vertical beam			Wheel Load parallel beam	
		upper	lower	cantilever	upper	lower
design compressive strength of concrete fd	N/mm²	18.46	18.46	18.46	18.46	18.46
k1		0.85	0.85	0.85	0.85	0.85
K		17	17	17	17	17
stress of concrete due to permanent load σ p	N/mm²	1.16	0.46	0.78	0.27	0.13
fatigue life N	times	540,000	540,000	540,000	540,000	540,000
design compressive strength of concrete frd		9.74	10.14	9.96	10.25	10.33
stress in concrete due to variable load σ 'crd		1.55	2.20	2.81	1.08	0.71
Examination result γ i× σ 'crd / (frd / γ b)		0.16 O.K	0.22 O.K	0.28 O.K	0.10 O.K	0.07 O.K

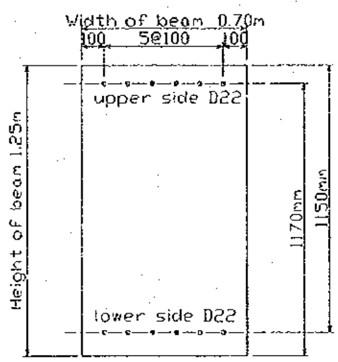
※Section force is the same value as what was used by examination of reinforcing bar.

・Dimension of an examination section (Beam)

Vertical to the face line



Parallel to the face line



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b) Examination of Fatigue Limit of Shear

References/ Notes

Examination of fatigue limit of shear checks the safety of only a concrete portion. When design shear force exceeds design shear fatigue capacity of a concrete portion, the stress of shear reinforcement is examined.

Examination of fatigue limit of shear of a concrete portion checks the following formulas.

$\gamma i \times Vrd / Vrcd \leqq 1.0$

$Vrcd = Vcd \times (1 - Vpd / Vcd) \times (1 - \log N / 11)$

where、 Vrd : design shear force produced by variable load

Vrcd : design shear fatigue capacity of member without shear reinforcement

Vcd : design shear capacity of concrete

(see examination of shearing force of ultimate limit state)

N : fatigue life

Vpd : design shear force produced by permanent load

When not filling the above-mentioned formula, the following formulas examine shear reinforcement.

$\gamma i \times \sigma wrd / (fwrd / \gamma b) \leqq 1.0$

design stress in shear reinforcement due to permanent load $\sigma wpd = \dfrac{(Vpd + Vrd - k_2 \times Vcd) \times s}{Aw \times z \times (\sin \alpha s + \cos \alpha s)} \times \dfrac{Vpd + Vcd}{Vpd + Vrd + Vcd}$

design stress in shear reinforcement due to variable load $\sigma wrd = \dfrac{(Vpd + Vrd - k_2 \times Vcd) \times s}{Aw \times z \times (\sin \alpha s + \cos \alpha s)} \times \dfrac{Vrd}{Vpd + Vrd + Vcd}$

design fatigue strength for reinforcing bar (shear reinforcement) $fwrd = 190 \times \dfrac{10^{\alpha}}{N^{k}} \times \left(1 - \dfrac{\sigma wpd}{fud}\right) / \gamma s$

where、 Aw : area of shear reinforcement within distance "s"

s : spacing of vertical shear reinforcements

z : distance from compression resultant to centroid of tension reinforcement (=d/1.15)

d : effective depth

αs : angle between shear reinforcement and axis of member

fud : design tensile strength of steel (=490 / 1.05 = 466.67 N/mm^2)

N : fatigue life

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$\alpha = k_0 \times (0.81 - 0.003 \times \phi)$ ($k_0 = 1.0$、 ϕ : diameter of reinforcing bar)

$k = 0.12$ 、 $k_2 = 0.5$

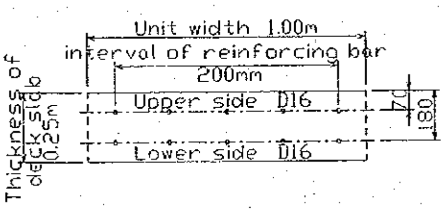
Since shear reinforcement has the bent portion, design fatigue strength, fwrd, is taken as 50% of value of a calculation result.

(i) Deck Slab

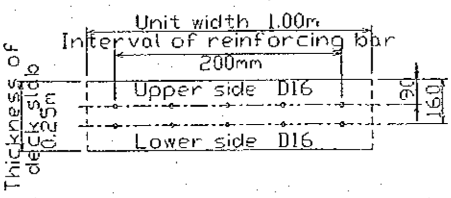
	unit	Parallel to face line		Vertical to face line	
		Wheel Load (Distribution)	Wheel Load (Partial distribution)	Wheel Load (Distribution)	Wheel Load (Partial distribution)
Vpd	kN	9.70	9.70	10.86	10.86
Vrd	kN	32.44	33.06	36.30	24.69
Vcd	kN	117.03	117.03	108.22	108.22
Vrcd	kN	51.40	51.40	46.62	46.62
Examination result $\gamma i \cdot Vrd / Vrcd$		0.631	0.643	0.779	0.530
Necessity for examination of shear reinforcement		without necessity	without necessity	without necessity	without necessity
α		—	—	—	—
k		—	—	—	—
diameter of reinforcing bar ϕ	mm	—	—	—	—
k_0		—	—	—	—
design tensile strength of steel fud	N/mm^2	—	—	—	—
design stress in shear reinforcement due to permanent load σ wpd	N/mm^2	—	—	—	—
fatigue life N	times	—	—	—	—
design fatigue strength for reinforcing bar fwrd		—	—	—	—
design stress in shear reinforcement due to variable load σ wrd		—	—	—	—
Examination result $\gamma i \cdot \sigma wrd / (fwrd / b)$		—	—	—	—

・Dimension of an examination section

Parallel direction to the face line



Vertical direction to the face line



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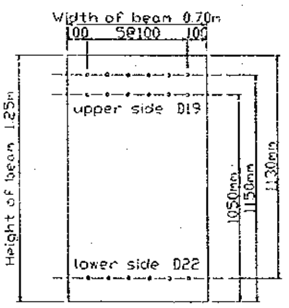
(ii) Beam

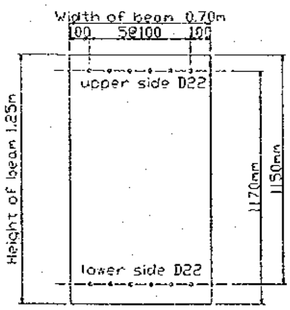
	単位	Vertical direction beam to the face line		Parallel direction beam to the face line
		Wheel load	Wheel Load (Cantilever)	Wheel load
Vpd	kN	112.54	92.10	56.03
Vrd	kN	273.45	242.86	202.21
Vcd	kN	269.71	269.71	271.71
Vrcd	kN	75.26	85.05	103.28
Examination result $\gamma i \cdot Vrd / Vrcd$		3.633	2.855	1.958
Necessity for examination of shear reinforcement		with necessity	with necessity	with necessity
α		0.771	0.771	0.771
k		0.12	0.12	0.12
diameter of reinforcing bar ϕ	mm	13	13	13
k_0		1.0	1.0	1.0
design tensile strength of steel fud	N/mm²	466.67	466.67	466.67
design stress in shear reinforcement due to permanent load σ wpd	N/mm²	58.80	48.09	29.87
fatigue life N	回	540,000	540,000	540,000
design fatigue strength for reinforcing bar fwrd		95.75	98.27	102.55
design stress in shear reinforcement due to variable load σ wrd		42.06	32.28	18.43
Examination result $\gamma i \cdot \sigma wrd / (fwrd / b)$		0.44 O.K	0.33 O.K	0.18 O.K

・Dimension of an examination section (Beam)

Vertical to the face line



Parallel to the face line



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7) Design of Pile Head

Because the thickness of the concrete above the pile heads is small in pier, the embedment length of pile is calculated on the assumption that there is no punching shear of concrete and the loads are transmitted from the beams to piles only through the bonding between the pile circumference and concrete without assistance of shear strength of concrete against punching

(1) Section Force

Maximum axial force Sd = 765.6 kN

(Earthquake parallel direction to the face line)

Maximum pile head moment M_0 = 799.0 kN・m (Earthquake Sea→Land)

(2) Examination to pile head moment

The necessity embedding length to pile head moment computes from the following formulas.

$$L = \sqrt{(6 \times M_0 / (B \times f'ad))} \times \gamma b \times \gamma i$$

where、L : necessity embedding length to pile head moment (mm)

M_0 : pile head moment (= 799,000,000 N・mm)

B : diameter of the pile (700 mm)

f'ad : design bearing strength of superstructure

(The same value as the design compression strength of concrete)

(= 24 / 1.3 = 18.5 N/mm²)

γb : member factor (=1.15)

γi : structure factor (=1.0 (earthquake condition))

$$L = \sqrt{(6 \times 799{,}000{,}000 / (700 \times 18.5))} \times 1.15 \times 1.0 = 700 \text{ mm}$$

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References/ Notes

(3) Examination to axial force

The necessity embedding length to axial force computes from the following formulas.

$L = P / (\phi \times fbod / \gamma b)$

where、 P : calculated value of axial force acting on pile in design (=Sd=765,600 N)

ϕ : outer perimeter of the cross section of pile (diameter : 700 mm)

fbod : design bond strength between the pile and concrete ($=0.11 \times f'ck^{2/3} / \gamma c = 0.11 \times 24^{2/3} / 1.3 = 0.704$ N/mm^2)

f'ck : characteristic compressive strength of concrete

γc : material factor for concrete

γb : member factor

$L = 765{,}600 / (700 \times \pi \times 0.704 / 1.0) = 495$ mm

(4) Determination of the embedding length of piles

The embedding length to superstructure of a steel pipe pile does as follows from the above-mentioned examination result.

L = 700 mm

References/ Notes

8) Examination of welding of reinforcing bar and steel pipe pile

The lower reinforcing bar of a beam is welded to the plate attached in the steel pipe pile. The diameter and number of lower reinforcing bar of the parallel and vertical directions beam to the face line are as follows.

Diameter : D22 、 Number : 6 pieces

(1) Examination of thickness of plate

The thickness (t) of a plate is calculated by the following formula.

$t = T / (L \times \tau_{ta})$ (mm)

where、T : Action tension (N)

$T = As \times \sigma_{sa} \times n$

As : cross-section area of reinforcing bar (mm^2) (D22 $As = 387.1 mm^2$)

σ_{sa} : allowable stress of reinforcing bar (SD345 : =176 N/mm^2)

n : number of reinforcing bar (=6 pieces)

L : Welding length of a plate

τ_{ta} : allowable tensile stress for steel at welded zone

(SS400 =140 N/mm^2)

・Welding length of a plate

The outer perimeter of steel pipe pile is 700mm, and a plate is divided into four.

$L = \pi \times 700 / 4 = 550$ m

・Action tension

$T = 387.1 \times 176 \times 6 = 408{,}778$ N

・Thickness of plate

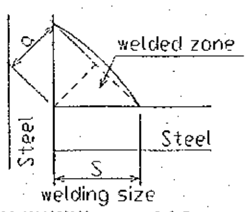
$t = 408{,}778 / (550 \times 140) = 5.3$ mm → 9.0mm

(2) Examination of the welding of steel pipe pile and a plate

Welding size is made into what satisfies the following formulas.

$\tau_{ts} = T / (a \times L) \leqq \tau_{ta}$

The sign of an upper formula is shown in the right figure.



where $a = 0.7 \times a$

Welding size is set to 9mm.

$\tau_{ts} = 408{,}778 / (0.7 \times 9 \times 550) = 118.0\ N/mm^2 \leqq 140\ N/mm^2$ O.K

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(3) Examination of the welding of a plate pile and reinforcing bar

The welding length of reinforcing bar computes by the following formulas.

$l = \sigma_{sa} \times As / (\sqrt{2} \times \lambda \times \tau_{sa})$

where λ : welding size (=D / 3 D : diameter of reinforcing bar)

τ_{sa} : allowable shearing stress for steel at welded zone (= 80 N/mm^2)

$l = 176 \times 387.1 / (\sqrt{2} \times (22 / 3) \times 80) = 82.1$ mm

Therefore, welding length is set to $l = 100$ mm.

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