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RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF STRUCTURES BY PRESTRESSED CONCRETE PANEL COMPOSITE SLAB METHOD

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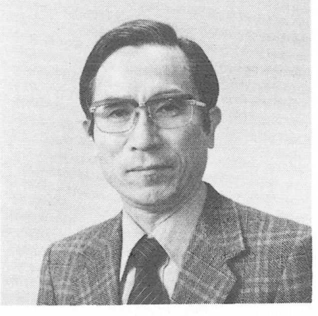
SYNOPSIS

The Committee on Concrete in the Japan Society of Civil Engineers (JSCE) organized the Subcommittee on Recommendations for Design and Construction of Structures by Prestressed Concrete Panel Composite Slab Method in 1984 when private companies entrusted the research to JSCE.

The "recommendations for design and construction of structures by prestressed concrete panel composite slab method" was drawn up in 1987 by the research subcommittee on the basis of the results of research and actual applications in construction work.



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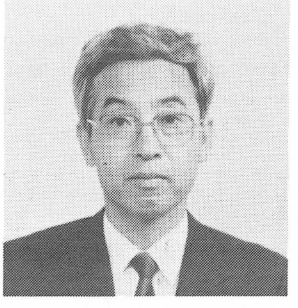

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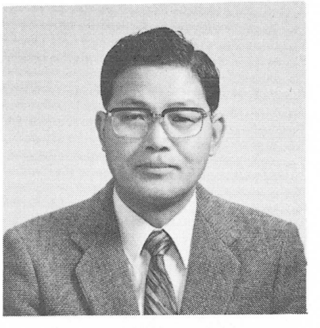

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RECOMMENDATIONS FOR DESIGN AND CONSTRUCTION OF STRUCTURES BY PRESTRESSED CONCRETE PANEL COMPOSITE SLAB METHOD

CHAPTER 1 GENERAL

1.1 Scope of Application

(1) These Recommendations give general standards regarding matters necessary in particular in design and construction of structures using prestressed concrete panel composite slabs. Matters not covered in these Recommendation shall be in accordance with "Standard Specifications for Concrete" of the Japan Society of Civil Engineers.

(2) The prestressed concrete panels considered in these Recommendations shall satisty the following conditions:

(i) That they are factory-manufactured products by pretensioning systems,

(ii) That the thickness of the panel is not less than 7 cm,

(iii) That the width of the panel is not less than 0.5 m and is 1.0 m as a standard,

(iv) That the length of the panel is not less than 0.9 m in case of using SWPD3 2.9-mm 3-wire strands and not less than 1.2 m in case of using SWPR7A 7-wire 9.3-mm strands,

(v) That the top surface of the panel has furrows in the direction of the prestressing steel with the spacings between ridges and depression of the furrows in a range from 40 to 50 mm, with moreover, the height differential between ridge and depression about 4 mm.

(3) Prestressed concrete panel composite slabs considered in these Recommendations shall, in principle, satisfy the following conditions:

(i) That the prestressed concrete panels shall be laid out without gaps in a manner that the direction of the prestressing steel tendons will be in the direction of span of the prestressed concrete panels with concrete placed on top in situ for integration.

(ii) That the thickness of concrete placed in situ is not less than 1.5 times the thickness of the prestressed concrete panel.

(Comments)

(1) These Recommendations are applicable not only to deck slabs of highway bridges, but also the deck slabs of railway bridges and landing piers, and cover slabs of waterways. However, since use of prestressed concrete panel composite slabs has been mostly as deck slabs of highway bridges, (2) and (3) of this article were written with the deck slabs of highway bridges mainly kept in mind. In case of considering structures other than deck slabs of highway bridges, if thorough studies were to be made observing the aims of these Recommendations, it will be possible for these Recommendations to be applied even when outside the scopes of application of (2) and (3). Furthermore, the Highway Bridge Specifications should be referred to when applying to the deck slabs of highway bridges, and the related specifications and standards when applying to other structures.

(2) Because prestressed concrete panels are comparatively thin, they were limited to factory products made by pretensioning systems. It is necessary for these panels to be manufactured at plants capable of quality control of a degree at least equal to other JIS-approved prestressed concrete products. Furthermore, the specified strength of concrete used for the prestressed concrete panels must be not less than 500 kgf/cm^2 as specified in 2.1.1(5).

The practical minimum thickness with which reliable prestressed concrete panels can be made is generally 6 to 7 cm. Hence, the minimum thickness of a prestressed concrete panel was set at 7 cm so that it would be possible to secure the required cover for prestressing steel and reinforcing steel arranged inside the panel. It is permissible for this thickness to be the average thickness taking into consideration the irregularities at the top surface. The standard is for the thickness of the prestressed concrete panel not to vary over the length of the panel, but it is permissible for the thickness to be increased in part. Furthermore, the standard is for equal thickness over the breadth of the panel, but it is permissible for a web or some other contrivance to be provided.

If the width of the prestressed concrete panel is too small, strength against concentrated loads during construction will be insufficient, while the strength reduction effect resulting from making holes for attaching accessories will be great and, therefore, the minimum width was made 0.5 m.

If the width of the prestressed concrete panel is too large, handling on the job will become difficult, while after setting of the panel, the ill effect of lateral bending due to unevenness of the bearing parts of the panel will be increased. Furthermore, convenience in construction was taken into account and the standard width of the prestressed concrete panel was made 1.0 m. Still further, the width of a panel actually manufactured is to be about 2 mm smaller than assumed in design giving consideration to errors in manufacture and construction.

For the prestress transferred to the concrete panel through the medium of bond between prestressing steel and concrete to be of the required value it is necessary to have the required length of transmission zone from the end of the panel. The required transmission length will differ according to the type of the prestressing steel used and, therefore, the length of the prestressed concrete panel was designated according to the prestressing steel to be used. However, when the prestressed concrete panel is to be used for parts where very large moments do not occur such as overhangs, the length of the panel may be made shorter if safety has been confirmed by calculations.

Regarding the problem of integrating prestressed concrete panels with cast-in-place concrete at construction joints, there have been many studies made in the past, and it has been ascertained that the panels will behave integrally with cast-in-place concrete if the panels are finished with rough surfaces of the degree of having grid patterns made on their tops. However, the reliability must be increased further for this method to be widely used and, therefore, the ridges and depressions as in this clause were specified. If it is confirmed through experiments or other means that performance at least equivalent to that of the ridges and depressions in this clause is obtained, concavities and convexities of other shapes such as diamond shapes may be used.

(3) For the prestressed concrete panel composite slab to act as a slab, it is necessary for the thickness of the cast-in-place concrete in relation to that of the prestressed concrete panel to be of a ratio above a certain value. It has been confirmed through studies and experiments in the past that for practical

purposes the prestressed concrete panel composite slab can be considered to behave as an isotropic slab if the thickness of the cast-in-place concrete were to be made 1.5 times that of the prestressed concrete panel and an appropriate amount of distribution bars is arranged.

1.2 Definition

Terms used in these Recommendations shall be defined as follows:

Prestressed concrete panel --- A prestressed concrete panel serving as the form and support of cast-in-place concrete, along with which it has the purpose of becoming of composite nature with the cast-in-place concrete after the latter has hardened.

Prestressed concrete panel composite slab --- A slab of composite structure through integration of prestressed concrete panels and cast-in-place concrete.

Joint filler --- A material for connection between the bottom surface of a prestressed concrete panel and its bearing surface.

Joint sealant --- A sealant used at joints between prestressed concrete panels to prevent leakage of mortar when placing cast-in-place concrete.

1.3 Notation

The following notations are used in these Recommendations.

f'_{ck} : Specified strength of concrete (characteristic compressive strength of concrete).

f_{puk} : Characteristic tensile strength of prestressing steel

f_{pyk} : Characteristic yield strength of prestressing steel

CHAPTER 2 MATERIALS

2.1 Quality of Material

2.1.1 Concrete Materials and Concrete

(1) Cements

Cements shall conform to the requirements of JIS R 5210 "Portland Cement."

(2) Mixing water

Mixing water shall not contain an injurious amount of impurities such as oil, acid, salts, organic impurities, suspended solids and so on which adversely affect the quality of concrete, prestressing steel and reinforcement.

(3) Aggregates

(i) Aggregates shall be clean, hard, firm, durable, and have proper grading. A harmful amount of dust, mud, organic impurities, chlorides and so on shall not be contained.

(ii) The maximum size of coarse aggregate used for prestressed concrete panels shall be about 15 mm.

(4) Admixtures

(i) Air-entraining agents, water-reducing agents and air-entraining and water-reducing agents to be used as chemical admixtures shall conform to the requirements of JIS A 5204 "Chemical Admixtures for Concrete."

(ii) For admixtures other than (i) above, it is necessary to test their quality and study the proper methods of use thoroughly.

(5) Concrete

(i) Concrete shall have the required strength, durability, and watertightness with minimum variation in quality. It shall have the quality to protect the steel as well. Furthermore, it shall also have suitable workability during concreting work.

(ii) The specified strength of concrete used for prestressed concrete panels shall be not less than 500 kgf/cm^2.

(Comments)

(3) Thickness in the member cross section of a prestressed concrete panel is comparatively small while the quantity of steel is large, and it is not suitable to use coarse aggregate too large in size if concrete is to fill the space thoroughly. On the other hand, if the coarse aggregate were to be too small, a large amount of cement will be required and be uneconomical. Consequently, for practical purposes, a maximum size of coarse aggregate of about 15 mm will be suitable.

(5) A prestressed concrete panel, while being of comparatively small thickness, is required to have adequate strength and durability, and it is necessary to use good-quality concrete of low water-cement ratio. For these Recommendations, it was decided that concrete of specified strength not less than 500 kgf/cm^2

should be used in consideration of ease of manufacturing concrete to attain this objective and of manufacturing cost.

2.1.2 Prestressing Steel Used for Prestressed Concrete Panel

The prestressing steel tendons used for prestressed concrete panels shall be SWPD3 2.9-mm 3-wire strands or SWPR7A 7-wire 9.3-mm strands meeting the requirements of JIS G 3536 "Uncoated Stress-Relieved Steel Wire and Strand for Prestressed Concrete."

(Comments)

If prestressing tendons of large diameter were to be used, not only will the length of the transmission zone become long, but when subjected to flexure in a direction perpendicular to the direction of placement of prestressing tendons, cracks along the prestressing tendons are liable to occur in concrete at the underside of the steel, and there will be a risk that anchorage of the prestressing steel will become inadequate. On the other hand, if prestressing tendons too small in diameter were to be used, there would be cases in which placing the tendons inside the prestressed concrete panel will be difficult. It was for these reasons that the varieties of prestressing steel were limited to those in this clause.

If prestressing tendons were to be arranged at the centroidal axis of the prestressed concrete panel, there would be the risk of the panel being warped downward when transferring prestress as a result of the influence of surface finishing of the panel top, or only a slight error in laying out the steel. It is desirable for prestressing steel in the prestressed concrete panel to be draped slightly below the centroidal axis of the panel in order to avoid such deflection. It is also necessary to provide additonal reinforcing bars under the prestressing tendons in a direction perpendicular to the tendons. Consequently, in order to secure cover of 2.5 cm, in case the thickness of the panel is 7 cm, the prestressing tendons would be limited to SWPD3 2.9-mm 3-wire strands. On the other hand, in case the thickness of the panel is 8 cm or more, it will be possible to use either SWPD3 2.9-mm 3-wire strands or SWPR7A 7-wire 9.3-mm strands.

2.1.3 Reinforcement

(1) Reinforcing bars

In principle, steel bars meeting the requirements of JIS G 3112 "Steel Bars for Concrete Reinforcement" or JIS G 3117 "Rerolled Steel Bars for Concrete Reinforcement" shall be used for reinforcement.

(2) Additional bars used for prestressed concrete panels

For additional bars arranged underneath the prestressing tendons, bars in coils meeting the requirements of JIS G 3191 "Dimensions, Weight and Permissible Variations of Hot Rolled Steel Bars and Bars in Coils," may be used other than those stipulated in (1) above.

(Comment)

(2) Steel bars for reinforced concrete of D6 denomination often are shipped in the form of bars in coils, and bars in coils were made acceptable from the

standpoint of availability of materials. In case of designing prestressed concrete panel composite slabs in accordance with 4.3.3, it will be permissible to use welded wire fabric meeting the requirements of JIS G 3551 "Welded Steel Wire Fabrics," as additional bars.

2.1.4 Materials for Installing Prestressed Concrete Panels

(1) Joint filler

(i) Joint filler shall be provided between prestressed concrete panels and their bearing surfaces and shall be a material facilitating good contact and adjusting surface irregularities between the two.

(ii) In case of a steel bearing surface, it shall be desirable for the support to be such that a thickness of 1.0 to 1.5 mm can be secured even when prestressed concrete panels have been installed on top and the support has been subjected to compression.

(iii) In case of a concrete bearing surface with which it would be difficult for the location of prestressed concrete panel installation to be finished to a precision of the same degree as a steel bearing surface, it will be permissible for joint filler and non-shrink mortar to be used together. This non-shrink mortar shall be of equal quality as the material specified in (2) below.

(2) Joint sealant

Joint sealant used for prestressed concrete panels shall possess the required strength and watertightness, and be of good working properties.

(3) Lifting device

Lifting devices for installation to be provided in a prestressed concrete panel shall be amply capable of withstanding the dead weight of the panel, and shall be of a material equal or better than the SR 24 round bar specified in JIS G 3112 "Steel Bars for Concrete Reinforcement."

(Comments)

(1) Joint filler must be a material that will not peel off or be prominently deformed before installation of prestressed concrete panels. In general, sponge tape coated with adhesive on one side or a material of equivalent properties will be acceptable (see 6.2.3).

(2) In general, a non-shrink mortar is to be used as the joint sealant. The quality standards for this mortar is to be according to Appendix 2, "Proposed Recommended Practice for Filling Mortar Using Expansive Admixture," of the JSCE "Recommendations for Design and Construction of Expansive Concrete."

(3) Locations where prestressed concrete panels are installed are generally where work at high elevations is involved, and in the event a lifting device is damaged it is conceivable that a serious accident will occur. Therefore, thorough studies must be made beforehand regarding strength of the material.

2.2 Design Values of Concrete

The strengths, fatigue strength, stress-strain curve, Young's modulus, Poisson's ratio, coefficient of thermal expansion, creep coefficient, etc. of concrete to be used for design calculations shall be according to 3.2 in the Design Volume of the "Standard Specifications for Concrete," The creep coefficient of concrete in case the age of the concrete when loading is 3 days or less shall be determined by a suitable method.

(Comments)

Design values of concrete shall be specified as follows.

(1) Characteristic values of concrete strengths

(i) Characteristic values of concrete strengths shall be based on 28-day tests as a rule. Compression test shall be in accordance with JIS A 1108 "Method of Test for Compressive Strength of Concrete."

(ii) When ready-mixed concrete in accordance with JIS A 5308 is used, the nominal strength specified by the purchaser may be used generally as the characteristic concrete strength f'_{ck}.

(2) Design values for ultimate limit states

(i) Design compressive strength of concrete to be used for check for the ultimate limit state may be calculated by Eq. (C 2.1).

$$f_{cd}' = f_{ck}'/\gamma_c \qquad \text{(C 2.1)}$$

(ii) The material factor of concrete may be taken as 1.3, in general for checking the ultimate limit state.

(iii) An idealized stress-strain curve given in Fig.C 2.1 may be used in general for examining the ultimate limit state of sectional failure of members subject to flexural moment or to flexure and axial forces.

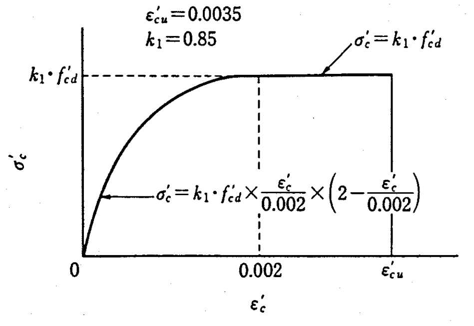


Fig.C 2.1 Idealized stress-strain curve for concrete

(3) Design values for serviceability limit states

(i) The stress-strain curve of concrete may be assumed as linear for check for serviceability limit states. The modulus of elasticity of concrete Ec may be equal to the value shown in Table C 2.1 in general. Poisson's ratio of concrete may be 0.2 within elastic range in general. However, it shall be zero when cracking is allowed due to tension.

Table C 2.1 Young's modulus of concrete

f'_{ck} (kgf/cm^2)	180	240	300	400	500	600
E_c ($10^5 kgf/cm^2$)	2.2	2.5	2.8	3.1	3.3	3.5

(ii) Coefficient of thermal expansion of concrete may be 10×10^{-6}/°C in general.

(iii) Drying shrinkage strain of concrete may generally be equal to the values given in Table C 2.2. Drying shrinkage strain of concrete for computation of statically indeterminate forces by the elastic theory may be equal to 150×10^{-6} in general. When this value is used, however, influences of creep shall not be added.

Table C 2.2 Drying shrinkage strain of concrete ($\times10^{-6}$)

Environmental conditions	Age*				
	before 3 days	4-7days	28 days	3months	1 year
out-door	250	200	180	160	120
in-door	400	350	270	210	120

* Starting age of drying when considering shrinkage in design

(iv) Creep strain of concrete may be obtained generally by Eq.(C 2.2), assuming that it is proportional to elastic strain induced by an applied stress.

$$\varepsilon_{cc}' = \varphi \sigma_{cp}' / E_c \qquad (C\ 2.2)$$

where,

ε_{cc}' : compressive creep strain of concrete
φ : creep factor
σ_{cp}' : applied compressive stress
E_c : modulus of elasticity of concrete

Creep factors used for prestressed concrete may be equal to the values given in Table C 2.3 in general. When a creep strain is obtained from Eq.(C 2.2) using the creep factors shown in Table C 2.3, Ec shall be the value at age of 28 days.

Table C 2.3 Creep factor of concrete

Type of cement	Environmental conditions	Age when applying prestress	
		3 before	4~7 days
high-early strength portland cement	out-door	3.0	2.6
	in-door	-----	4.0
ordinary portland cement	out-door	-----	2.8
	in-door	-----	4.3

2.3 Design Values of Steel

The strengths, fatigue strength, stress-strain curve, Young's modulus, Poisson's ratio, coefficient of thermal expansion, relaxation ratio of prestressing steel, etc. to be used for design calculations shall be according to 3.3 in the Design Volume of the "Standard Specifications for Concrete," provided that the fatigue strength of prestressing steel and the apparent relaxation ratio before introduction of prestress and in case of being subjected to the influence of high temperature shall be determined by a suitable method.

(Comments)

Design values of steel shall be specified as follows.

(1) Characteristic values of steel strengths

For reinforcing steel in accordance with JIS, the characteristic yield strength value f_{yk} and the characteristic tenside strength value f_{uk} may be regarded as the lower limit values specified in JIS. The nominal cross-sectional area, in general, may be used as the area of reinforcing steel for design.

Characteristic values of SWPD3 2.9-mm 3-wire strands, SWPR7A 7-wire 9.3-mm strands, SD30A, SD30B and SD35 may be equal to the values given in Table C 2.4.

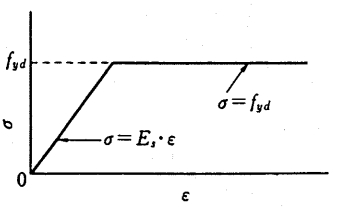
Table C 2.4 Design values of steel

Type of steel		Yield strength (kgf/cm^2)	Tensile strength (kgf/cm^2)	Area (cm^2)	Diameter (cm)
Prestressing steel	SWPD3	17 500	19 500	0.1982	0.458
Prestressing steel	SWPR7A	15 000	17 500	0.5161	0.93
Reinforcing bar	SD30A	3 000	4 500	----	----
Reinforcing bar	SD30B	3 000	4 500	----	----
Reinforcing bar	SD35	3 500	5 000	----	----

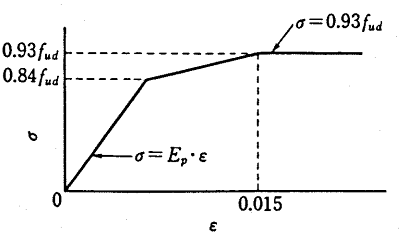
(2) Design values for ultimate limit state

(i) The design values to be used for the check for the ultimate limit state may be equal to the characteristic values.

(ii) As for the examination for the ultimate limit state, the stress-strain curve represented in Fig.C 2.2 may be generally used.



(a) Reinforcing bar



(b) Prestressing wire strand

Fig.C 2.2 Idealized stress-strain curve for steel

(3) Design values for serviceability limit state and fatigue limit state

(i) The design fatigue strength of a deformed bar f_{srd} may be obtained by Eq.(C 2.3) as a function of the fatigue life N and the stress σ_{sp} of a deformed bar due to permanent load.

$$f_{srd}=1\,900(10^{\alpha}/N^{k})(1-\sigma_{sp}/f_{ud})/\gamma_s \quad \text{(kgf/cm2)} \qquad \text{(C 2.3)}$$

for $N \leqq 2 \times 10^6$ (cycles)

where,

$f_{srd} \leqq f_{yd} - \sigma_{sp}$

f_{ud}: design tensile strength of deformed bar

γ_s : material factor for deformed bar, which may be generally regarded as 1.0

i) It is a principle that the values of α and k shall be determined by fatigue tests.

ii) When the fatigue life N is less than or equal to 2×10^6 cycles, the values of α and k, in general, may be obtained by Eq. (C 2.4).

$$\alpha = k_0\,(0.82 - 0.003\,\phi) \qquad \text{(C 2.4)}$$
$$k = 0.12$$

where, k_0 : a factor, which may be generally regarded as 1.0

(ii) The design fatigue strength of prestressing steel shall be properly determined based on the fatigue strength obtained by the tests and so on.

(iii) The stress-strain curve for steel may be assumed as linear. The modulus of elasticity for reinforcing steel, in general, may be regarded as the values represented in Table C 2.5.

Table C 2.5 Young's modulus of steel

Type of steel	Young's modulus (10^6kgf/cm^2)
Prestressing steel	2.0
Reinforcing bar	2.1

(iv) The coefficient of thermal expansion of reinforcing steel, in general, may be regarded as 10×10^{-6}/ C.

(v) The apparent relaxation ratio of prestressing steel γ in order to calculate the decrease in prestress, in general, may be regarded as 4% for before prestressing and 5% after prestressing. In case prestressing steels are put in hot temperature, the apparent relaxation ratio shall be added by 2%.

CHAPTER 3 DESIGN OF PRESTRESSED CONCRETE PANEL

3.1 General

(1) Prestressed concrete panels shall be designed in a manner that damage will not occur from the time of fabrication until installation in the field.

(2) Prestressed concrete panels shall be designed in a manner that they will fulfill the roles of formwork and supports.

(3) Prestressed concrete panels shall be designed in a manner that they will become integral with cast-in-place concrete and fulfill the roles of a composite slab.

3.2 Check for Serviceability Limit State

3.2.1 Method of Check

(1) The checks of (4), (5) and (6) shall be made for the serviceability limit state. Computation of strress intensity in such case shall be in accordance with 3.2.2.

(2) Effective prestress, dead weight of prestressed concrete panel, dead weight of cast-in-place concrete, and live load shall be considered as loads.

(3) The factor of safety may be taken generally as 1.0.

(4) The stress intensity of concrete immediately after prestressing shall satisty the following conditions:

(i) The axial compressive stress intensity due to prestressing shall be not more than 100 kgf/cm^2.

(ii) In case of composition of bending stress with prestress and dead weight of prestressed concrete panel, the minimum value of bending stress intensity in the same cross section shall be not less than three-fifths of the maximum value.

(5) When composing bending stress with effective prestress, dead weight of prestressed concrete panel, dead weight of cast-in-place concrete, and live load during construction of a composite slab, the bending compressive stress intensity of concrete shall be not more than 200 kgf/cm^2, while moreover, bending tensile stress shall not be produced in the concrete.

(6) The tensile stress intensity of prestressing steel shall satisfy the following conditions:

(i) It shall be not more than 0.8 f_{puk} and not more than 0.9 f_{pyk} during prestressing.

(ii) It shall be not more than 0.7 f_{puk} and not more than 0.85 f_{pyk} immediately after prestressing.

(iii) It shall be not more than 0.7 f_{puk} during construction of the slab.

(Comments)

(2) When calculating prestressing force as load, the influences of elastic

deformation, drying shrinkage, and creep of concrete, relaxation of prestressing steel, etc. must be taken into consideration.

Dead weight may be calculated with unit weights of prestressed concrete panel and cast-in-place concrete as 2500 kgf/m^3.

Live load would consist of the weights of workers, equipment for concrete placement, etc., and in general, may be taken to be 150 kgf/m^2.

(4) It is desirable for a large bending compressive stress to be made to act at a location where bending tensile stress acts during construction of a composite slab or when design load of a prestressed concrete panel composite slab is acting by making prestressing force and eccentricity of prestressing steel as large as possible, but with a thin member such as a prestressed concrete panel, excessive warping and buckling will be liable to occur. Consequently, a clause was provided to indirectly limit prestressing force and eccentricity.

According 11.6, Design Volume of the "Standard Specifications for Concrete," the bending compressive stress intensity and axial compressive stress intensity of concrete immediately after prestressing must be not more than $f_{ck}'/1.7$ and $f_{ck}'/2$, respectively, but these requirements will be automatically satisfied if (i) and (ii) are satisfied since the compressive strength of concrete is not less than 350 kgf/cm^2 at the time prestress is introduced (see 6.1.6).

(5) It was specified that composite compressive stress intensity must be not more than 200 kgf/cm^2 since the compressive strength of concrete when constructing the composite slab is not less than 500 kgf/cm^2 (see 6.3.1), and bending compressive stress intensity of concrete during action of permanent load is limited to 0.4 f_{ck}' according to 11.3.1(2) in the Design Volume of the "Standard Specifications for Concrete." Even when the compressive strength of concrete is higher than 500 kgf/cm^2, the composite bending compressive stress intensity is to be not more than 200 kgf/cm^2 in consideration of the fact that prestressed concrete panels are thin members.

3.2.2 Computation of Stress Intensity

Stresses in concrete and reinforcement in the section of prestressed concrete panel subjected to bending moment and axial force shall be computed based on the following assumptions.

(1) Fiber strain is proportional to the distance from the neutral axis.

(2) Both concrete and reinforcement are elastic bodies.

(3) The prestressed concrete panel shall be considered as a simply-supported beam. The span shall be considered as the length remaining on deducting half of the seating length at each end of the panel (see Fig. 3.1).

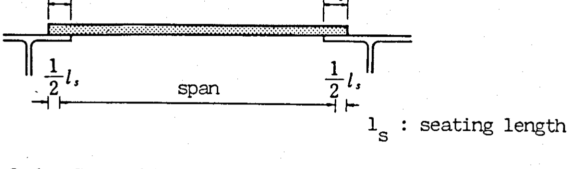


Fig. 3.1 Span length of prestressed concrete panel

(Comment)

(3) The span of a prestressed concrete panel will vary, although slightly, depending on whether it is immediately after prestressing, during construction of the composite slab, etc. However, if the length on deducting half of the seating length at each end of the panel is taken as the span, it will be possible to reduce the difference with the actual span of the prestressed concrete panel under such conditions.

3.3 Check for Ultimate Limit State

(1) With regard to the ultimate limit state, check of safety against bending moment and axial force shall be given adapting 6.2 in the Design Volume of the "Standard Specifications for Concrete."

(2) The dead weight of prestressed concrete panel, dead weight of cast-in-place concrete, and live load shall be considered as loads.

(3) In general, the structure factor may be taken as 1.15, the structural analysis factor as 1.0, the member factor as 1.15, the load factor as 1.15 (0.85 in case the smaller value will be hazardous), material factor of concrete as 1.3, and the material factor of steel as 1.0.

(Comment)

(1) As for check for the ultimate limit state, slabs subjected to combined bending moment and axial force shall be made so that the ratio of the design flexural capacity to the design bending moment is not less than the structural factor.

The design bending moment shall be calculated assuming that the prestressed concrete panel is to be a simply supported beam as specified in 3.2.2(3). Moreover, the design flexural capacity of the panel subjected to combined bending moment and axial force shall be calculated according to the following assumptions.

(i) Fiber strain is proportional to the distance from the neutral axis.

(ii) Tensile stress of concrete is neglected.

(iii) Stress-strain relationship of concrete is according to Fig. C 2.1 in principle. Compressive stress distribution of concrete may be assumed equivalent to rectangular compressive stress distribution (equivalent stress block) as shown in Fig. C 3.1 except when the compressive strain is distributed over the member cross section of prestressed concrete panel.

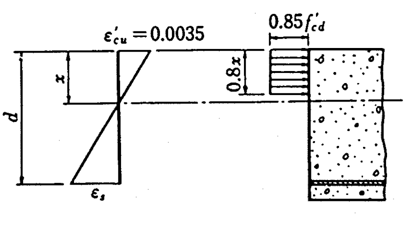


Fig. C 3.1 Equivalent stress block

(iv) Stress-strain relationship of steel is according to Fig. C 2.2 in principle.

Checks for bending moment and axial loads are ample for constructional loading in general. Considerations for shear and torsional moment may be omiited.

3.4 Structural Details

(1) Prestressing tendons in the prestressed concrete panel shall be arranged in a manner that prestress will be introduced uniformly throughout the width of the panel.

(2) Reinforcing bars in the prestressed concrete panel shall be placed in a quantity not less than 0.3 percent of the cross-sectional area of the concrete spaced equally as much as possible in the horizontal direction.

(3) Prestressing tendons and reinforcing bars shall be placed in a manner to secure cover of not less than 2.5 cm from the bottom and side surfaces of the prestressed concrete panel.

(4) Clearances between prestressing tendons in the horizontal direction shall be not less than 3 times the tendon diameter and not less than 4/3 times the maximum size of coarse aggregate.

(5) Clearances between main reinforcing bars in the horizontal direction and between main reinforcing bars and prestressing tendons in the horizontal direction shall respectively be not less than 3 cm, and not less than 4/3 times the maximum size of coarse aggregate.

(6) Clearances between prestressing tendons in the vertical direction shall be not less than 3 times the tendon diameter.

(7) Clearances between main reinforcing bars in the vertical direction, or between main reinforcing bars and prestressing tendons in the vertical direction shall respectively be not less than 2 cm, and not less than the diameter of the steel.

(8) Additional reinforcement placed underneath prestressing tendons in a direction perpendicular to the tendons shall be of a quantity not less than 0.2 percent of the cross sectional area of the concrete. However, this quantity shall be not less than 1 percent at anchorages of the prestressing tendons.

(9) The configuration of a side surface of the prestressed concrete panel shall be selected considering properties of bond between cast-in-place concrete and panel, and tight contact at joints between panels. In general, a configuration as shown in Fig. 3.2 is recommended.

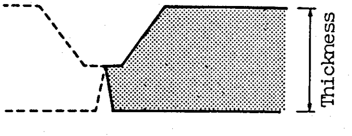


Fig. 3.2 Configuration of side surface of prestressed concrete panel

(10) It will be advisable for the width of a prestressed concrete panel as fabricated to be slightly smaller than the standard width giving consideration

to errors in fabrication and construction. In case of installation at a location where there are gradients in the span direction and perpendicular direction of prestressed concrete panels, the arraying of panels shall be done based on lengths giving consideration to such gradients.

(11) The seating length of a prestressed concrete panel shall be 5 cm at each end as a general rule, and shall be not less than 2.5 cm even in a special case.

(Comments)

(1) The prestressed concrete panel is a thin member of minimum thickness of 7 cm, while the standard width of the panel is 1.0 m and wide in comparison with the thickness. Therefore, it is necessary to arrange the prestressing tendons in a manner that prestress will be introduced uniformly throughout the width of the panel.

(3) The reason the requirements for cover of prestressing tendons and reinforcing bars were limited to the bottom and sides of the prestressed concrete panel is that even if the required cover were to be temporarily secured at the top surface of the panel, this part would be adequately covered by concrete cast in place on top.

(4),(5) In case the number of prestressing tendons to be placed in the prestressed concrete panel is large, it will be permissible for bundles using SWPD3 2.9-mm 3-wire strands with 2 strands per bundle the limit to be placed restricted to the horizontal direction. In this case, the clearance between bundled prestressing tendons in the horizontal direction must be not less than 3 times the diameter considering the bundled prestressing tendons to be a single tendon, and not less than 4/3 times the maximum size of coarse aggregate, while the clearance between bundled prestressing tendons and main reinforcing bars in the horizontal direction must be not less than 2 cm and not less than 4/3 times the maximum size of coarse aggregate.

(6),(7) To place prestressing tendons and main reinforcing bars in multiple levels is not possible in case the thickness of the prestressed concrete panel is about 7 cm and thin since the required cover cannot be secured. However, this stipulation was provided since placement in multiple levels can be done when the thickness is increased.

(8) It was decided to arrange additional bars underneath prestressing tendons in the prestressed concrete panel and in the direction perpendicular to the tendons in order to cope with tensile stresses perpendicular to the tendons produced in the concrete around anchorages of the tendons and with composite tensile stresses of lateral bending stresses of the panel due to external forces.

The ranges in which tensile stress are produced in concrete due to anchorage of prestressing tendons are as follows according to data such as results of tests previously performed:

Prestressing tendon SWPD3 2.9-mm 3-wire strand: 30 cm
Prestressing tendon SWPR7A 7-wire 9.3-mm strand: 50 cm

It was decided that additional bars not less than 1 percent of cross-sectional area of concrete should be placed in those ranges, and not less than 0.2 percent in other ranges.

(10) It is practical for the widths of the prestressed concrete panels actually fabricated to be made somewhat on the small side in consideration of errors in

fabricating and installing the panels. In case of the width of the prestressed concrete panel being 1.0 m, about 2 mm smaller is generally used.

(11) The lengths of seating of a prestressed concrete panel on supports, are generally determined by the lengths necessary for preventing falling off of the panel and from the relations with the locations of slide-off stoppers or slab anchors provided at the supports, and 5 cm at each end of the panel were taken to be standard. The shear stress intensities at the supports acting on a prestressed concrete panel at the time of slab construction are 2 to 3 kgf/cm^2 and comparatively small in case of thickness of cast-in-place concrete of 16 cm, thickness of prestressed concrete panel of 7 cm, and length of panel of 2 to 3 m. On varying the seating length of the prestressed concrete panel on a steel support at intervals of 1 cm from 1 cm to 5 cm and applying loads of about 8 times the load during slab construction, nothing abnormal was recognized. And, in case of seating length 2.5 cm, the shear cracking strength of the panel support was about 16 times the load when constructing the slab, and it may be judged that ample safety against shear failure and bearing failure were secured at the ends of the prestressed concrete panels. However, if the seating length of the prestressed concrete panel were to be too short, since there would be the risk of accidents such as sliding off of the panel due to errors in construction occurring, the minimum seating length was made 2.5 cm.

CHAPTER 4 DESIGN OF PRESTRESSED CONCRETE PANEL COMPOSITE SLAB

4.1 General

A prestressed concrete panel composite slab shall be designed in a manner that loads sustained after composition will be resisted as a unit.

4.2 Structural Analysis

Computations for determination of span length of a prestressed concrete panel composite slab, distribution width of concentrated load, bending moment, and shear force shall be performed adapting 13.1, Slabs, in the Design Volume of the "Standard Specifications for Concrete."

(Comments)

Structural analyses of prestressed concrete panel composite slabs shall be done adapting 13.1 in the Design Volume of the "Standard Specifications for Concrete" as follows.

(1) Span length of prestressed concrete panel composite slab for analyses shall be taken as the distance center-to-center of supports. However, for slabs with wide supports, the span length shall be considered the clear span plus slab thickness at midspan (see Fig. C 4.1).

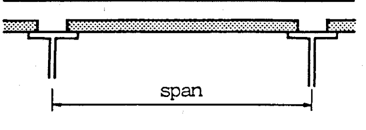


Fig. C 4.1 Span length of prestressed concrete panel composite slab

(2) Load acting on slab surface shall be distributed on the area at a distance 1/2 of the slab thickness from the periphery of the loaded area on the slab surface with the similar shape.

When concrete or asphalt-concrete is overlaid with slab, full thickness of the overlayer shall be added to the above distance. For overlayer with soft material, 3/4 the slab overlayer shall be considered as the distribution thickness (see Fig. C 4.2).

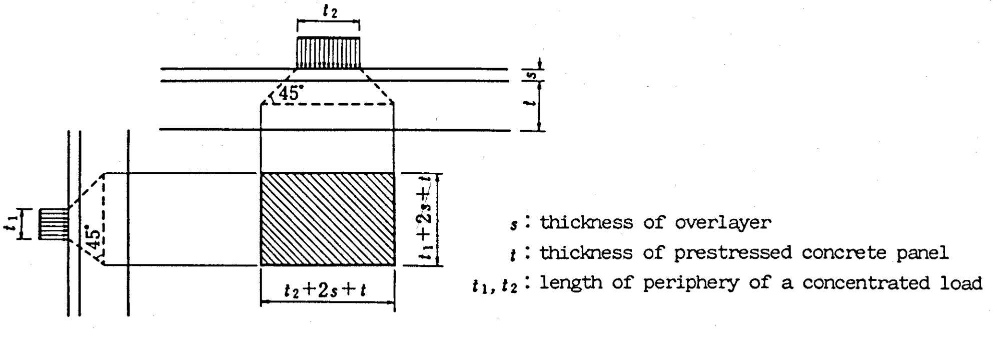


Fig. C 4.2 Distribution width of a concentrated load

(3) For simply supported one-way slab subjected to a concentrated load, the maximum moment per unit width may be computed as a beam with the effective width b_e defined in Eqs. (C 4.1-1) and (C 4.1-2).

(i) $c \geqq 1.2x(1-x/l)$ (see Fig. C 4.3(b))

$$b_e = v + 2.4x(1-x/l) \quad \text{(C 4.1-1)}$$

(ii) $c < 1.2x(1-x/l)$ (see Fig. C 4.3(c))

$$b_e = c + v + 1.2x(1-x/l) \quad \text{(C 4.1-2)}$$

where, x : distance between the section considered and the adjacent support
l : span length
v : load distribution width

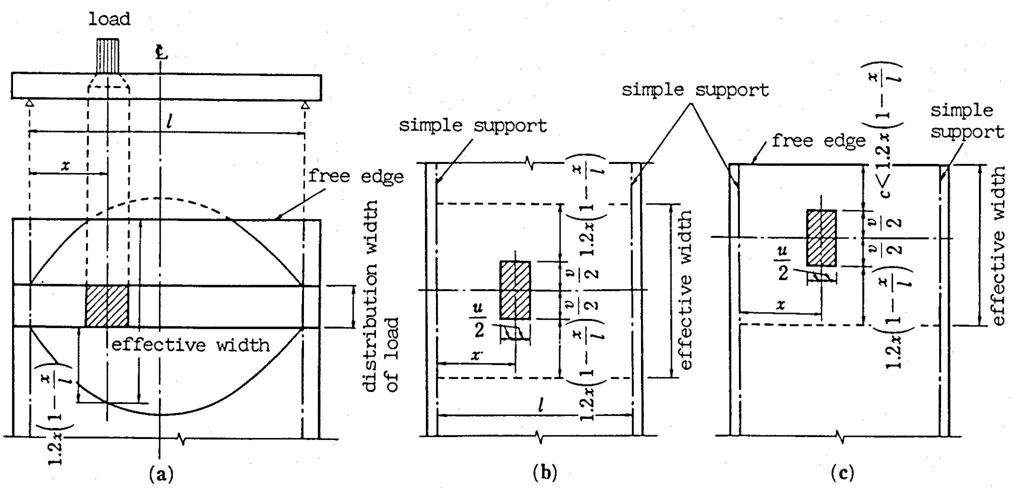


Fig. C 4.3 Effective width of prestressed concrete panel composite slab

For cantilevered parts of a prestressed concrete panel composite slab subjected to a concentrated load, the maximum moment per unit width may be computed as a beam with the effective width of two times of distance between a supported edge to a loading point.

For simply supported prestressed concrete panel composite slabs subjected to uniformly distributed loads, the maximum moment per unit width may be computed as a beam with the effective width.

(4) Design shall be in accordance with the provisions for beams assuming that a slab acts as a wide beam and resists shear by the cross section in one direction near support.

Generally accepted thin plate theories, charts, tables, numerical analysis, and a method specified in standards concerning the structure under consideration may also be used for bending moment and shearing force.

4.3 Check for Serviceability Limit State and Fatigue Limit State

4.3.1 Method of Check

(1) Checks shall be given to the serviceability limit state and the fatigue

limit state by one of the methods of 4.3.2, 4.3.3, and 4.3.4. Calculations of stress intensities in such cases shall be according to 4.3.5.

(2) As loads, indeterminate forces produced by loading of the prestressed concrete panel composite slab and that the prestressed concrete composite slab was restrained shall be taken into consideration.

(3) When considering flexural cracking, it shall be in accordance with 7.3 in the Design Volume of the "Standard Specifications for Concrete."

(4) The factor of safety may generally be taken as 1.0.

(Comments)

(1) The three methods of A, B, and C were given as methods of checking the serviceability limit state and the fatigue limit state, and any one of them may be used.

(2) In making the checks, only those acting after the prestressed concrete panels and cast-in-place concrete have been composed to become monolithic need be considered. However, it must be remembered that effective prestress, and stress due to the dead weight of the prestressed concrete panel and the dead weight of the cast-in-place concrete will be remaining in the concrete and the steel in the panel.

The prestressing force and the indeterminate forces produced by restraint of the prestressed concrete panel by such things as supports must be calculated giving consideration to elastic deformation, thermal deformation, drying shrinkage, and creep of the cast-in-place concrete, and relaxation of prestressing steel. However, computation of indeterminate forces may be omitted if it is confirmed by such means as trial calculations that they will not be large.

(3) Checks for flexural cracks shall be made as follows according to 7.3 in the Design Volume of the "Standard Specifications for Concrete."

The check for flexural cracks shall be made that the crack width, w, obtained from Eq. (C 4.2-1) is not greater than the permissible crack width, wa, in Table C 4.1, in general.

$$w = k_1[4c + 0.7(c_s - \phi)][\sigma_{se}/E_s(\text{or } \sigma_{pe}/E_p) + \varepsilon_{cs}'] \quad \text{(C 4.2-1)}$$

Increment of stress in reinforcing bars, σ_{se}, and that in prestressing steel, σ_{pe}, shall be obtained by member force, Se, which may be derived from Eq.(C 4.2-2)

$$S_e = S_p + k_2 S_r \quad \text{(C 4.2-2)}$$

where,

- S_p : member force due to permanent load
- S_r : member force due to variable load
- k_1 : coefficient
- k_2 : coefficient
- c : concrete cover (cm)
- c_s : center to center distance of reinforcing steel
- ϕ : diameter of steel
- ε_{cs}' : strain taken into account the influence of creep and drying shrinkage

Table C 4.1 Permissible crack width Wa(cm)

Type of steel	Environmental conditions for corrosion of reinforcement		
	Normal environment	Corrosive environment	Severe corrosive environment
Deformed bars Round bars	0.005c	0.004c	0.0035c
Prestressing steel	0.004c	-----	-----

* c : cover (cm)

4.3.2 Method A

(1) In computation of stress intensity produced inside the prestressed concrete panel, stress intensities produced due to effective prestress, the dead weight of the panel, and the dead weight of cast-in-place concrete shall also be considered.

(2) Consideration of flexural cracking shall also be given concerning the prestressed concrete panel.

(3) The design variable stress intensities of prestressing tendons and reinforcing bars shall be not more than the design fatigue strengths thereof.

(4) The tensile stress intensity of the prestressing steel shall be not more than 0.7 f_{puk}.

(5) The flexural compressive stress intensity of the concrete during action of permanent load shall be not more than 0.4 f_{ck}'.

(Comment)

This is a method aiming for faithful computation of stress intensities, and consists of computing the stress intensity of each construction stage giving consideration to how the prestressed concrete panel or cast-in-place concrete resists load. The method tolerates occurrence of flexural cracking of the prestressed concrete panel during action of design load and considers examination of flexural cracking and fatigue of steel. Compared with the other methods this method gives an economical design, but design calculations are the most complex.

4.3.3 Method B

(1) In computation of stress intensity produced inside the prestressed concrete panel, stress intensities produced due to effective prestress, the dead weight of the panel, and the dead weight of cast-in-place concrete shall be added together.

(2) Flexural tensile stress shall not be produced in the concrete of the prestressed concrete panel.

(3) The tensile stress intensity of the prestressing steel shall be not more than 0.7 f_{puk}.

(4) The flexural compressive stress intensity of the concrete during action of permanent load shall be not more than 0.4 f_{ck}'.

(Comment)

The computation method is approximately the same as for Method A, but by not tolerating occurrence of tensile stress inside the prestressed concrete panel, a prestressed concrete panel composite slab excelling in durability can be made, along with which design calculations can be done in a simple manner. In effect, considerations concerning flexural cracking of the prestressed concrete panel are unnecessary, while since the variations in steel stress intensities within the panel will be small, considerations of fatigue also will be unnecessary. Furthermore, at a location where positive bending moment acts, calculation may be done adapting 11.3.1(3) in the Design Volume of the "Standard Specifications for Concrete" where tensile reinforcement corresponding to the flexural tensile stress produced in the cast-in-place concrete may be arranged in the cast-in-place concrete, and the entire cross section of the prestressed concrete panel composite slab considered as effective. However, flexural cracking of cast-in-place concrete and fatigue of steel inside the cast-in-place concrete must be taken into consideration for a location where negative bending moment acts.

4.3.4 Method C

(1) The stress of concrete remaining in the prestressed concrete panel after construction of the composite slab shall be ignored. However, stress intensities produced due to effective prestress, the dead weight of the prestressed concrete panel, and the dead weight of the cast-in-place concrete shall be considered for the stress intensity of the prestressing steel in case of making the examinations of (3) and (4) below.

(2) Consideration of flexural cracking shall be given to the prestressed concrete panel also.

(3) The design variable stress intensities of prestressing tendons and reinforcing bars shall be not more than their design fatigue strengths.

(4) The tensile stress intensity of the prestressing steel shall be not more than 0.7 f_{puk}.

(5) The flexural compressive stress intensity of the concrete during action of permanent load shall be not more than 0.4 f_{ck}'.

(Comment)

This is a simplified computation method which uses assumptions differing from actual stress conditions. That is, compressive stress remaining in the prestressed concrete panel after construction of the composite slab is ignored, and it is assumed that all compressive stress intensities in the prestressed concrete panel composite slab before action of applied loads are zero. In this case, although it cannot be said to be economical compared with Method A, design calculations are simplified.

4.3.5 Computation of Stress Intensity

Computations of stress intensities of concrete and steel produced in the cross section of the prestressed concrete panel composite slab due to bending moment and axial force shall be based on the following assumptions:

(1) Fiber strain is proportional to the distance from the neutral axis of the

cross section.

(2) Concrete and steel are elastic bodies.

(3) Tensile stress of concrete is ignored.

4.4 Check for Ultimate Limit State

(1) With regard to ultimate limit state, checks of safety againt bending moment and axial-direction force, and check of safety against shear force shall be given respectively adapting 6.2 and 6.3 in the Design Volume of the "Standard Specifications for Concrete."

(2) As loads, the dead weight of the prestressed concrete panel, the dead weight of the cast-in-place concrete, and loads applied to the prestressed concrete panel composite slab shall be considered.

(3) In general, the structure factor may be taken as 1.15, the structural analysis factor as 1.0, the member factor as 1.15 in case of flexural strength and 1.3 in case of shear force, the load factor as 1.15 (0.85 in case the smaller value will be hazardous), the material factor of concrete as 1.3, and the material factor of steel as 1.0.

(Comments)

(1) With regard to the ultimate limit state, following three items shall be examined adapting 6.2 and 6.3 in the Design Volume of the "Standard Specifications for Concrete."

(i) Slab subjected to combined bending moment and axial force shall be designed so that the ratio of the design flexural capacity to the design bending moment is not less than the structural factor. The design flexural capacity may be calculated based on the assumptions described in Comment of 3.3, as a wide beam having the effective flange stipulated in Comment of 4.2(3).

(ii) The ratio of design shear capacity to the design shearing force shall be not less than the structural factor. The design shear capacity may be obtained by Eq.(C 4.3).

$$V_{yd} = V_{cd} = 0.9\beta_d \cdot \beta_p \cdot \beta_n \cdot f_{cd}'^{1/3} \cdot b_e \cdot d / \gamma_b \qquad \text{(C 4.3)}$$

$\beta_d = (100/d)^{1/4} \leqq 1.5 \quad (d: \text{cm})$

$\beta_p = (100 p_w)^{1/3} \leqq 1.5$

$\beta_n = 1 + M_o/M_d \leqq 2 \quad (N_d' \geqq 0)$

$\quad 1 + 2M_o/M_d \geqq 0 \quad (N_d' < 0)$

N'd : design axial compressive force

Md : design flexural moment

Mo : decompression moment necessary to cancel the fiber stress due to axial force at the edge of tension side corresponding to the design flexural moment Md.

γ_b : member factor

b_e : effective width

d : effective depth, distance from centroid of tensile steels in prestressed concrete composite slab to extreme compressive fiber.

p_w = As/(be·d)

As : cross-sectional area of tensile steels arranged in prestressed concrete panel and cast-in-place concrete.

f'cd: design compressive strength of concrete (kgf/cm^2)

(iii) When the loaded area is positioned far from free edges or openings and the eccentricity of the load is small, the design punching shear capacity Vpcd may be determined by Eq.(C 4.4).

$$V_{pcd}=0.6\beta_d\cdot\beta_p\cdot\beta_r\cdot f_{cd}'^{1/2}\cdot u_p\cdot d/\gamma_b \qquad \text{(C 4.4)}$$

$$\beta_d=(100/d)^{1/4}\leqq 1.5 \quad (d: \text{cm})$$
$$\beta_p=(100p)^{1/3}\leqq 1.5$$
$$\beta_r=1+1/(1+0.25u/d)$$

u : peripheral length of the loaded area

up : peripheral length of the design cross section which is located d/2 from the periphery of the loaded area

d,p : effective depth and reinforcement ratio which are defined as the average values for the reinforcement in two directions.

f'cd : design compressive strength of concrete, kgf/cm^2

γ_b : 1.3 in genral

The minimum thickness of the prestressed concrete panel composite slab will be 17.5 cm since the minimum thickness of the prestressed concrete panel is 7 cm, and a thickness at least 1.5 times that is necessary for the cast-in-place concrete. According to this, in case of application to a highway bridge, for example, punching shear will not be a problem, but depending on the structure, there can be a case in which a very large concentrated load will act compared with the thickness of the composite slab, and therefore, this clause was provided.

In the event the loading plane is close to a free edge or opening of the prestressed concrete panel composite slab, the fact that punching shear strength will be lowered must be taken into consideration.

4.5 Structural Details

For structural details, 13.1, Slabs, in the Design Volume of the "Standard Specifications for Concrete" shall be adapted.

(Comments)

The specifications for structural details are to be as described below adapting 13.1, Slabs, in the Design Volume of the "Standard Specifications for Concrete." The "main tensile steels" referred to here means prestressing tendons and reinforcing bars, while "cross-sectional area of main tensile steels" means the value in terms of reinforcing-bar cross-sectional area giving consideration to yield strengths.

(1) Center-to-center spacing between main tensile steels of the prestressed concrete panel composite slab shall be not more than 30 cm in a cross section where maximum bending moment occurs. It will be advisable for the spacing to be not more than 40 cm even at other cross sections.

(2) In case of being subject to uniformly-distributed load, the distribution bars of a simply-supported prestressed concrete panel composite slab shall be not less than 1/6 of the main tensile steel cross-sectional area per meter of slab width per meter of slab length.

In the event of being subject to concentrated load, α times the main tensile steel cross-sectional area per meter of slab width required against concentrated load shall be added to these distribution bars. This α shall be in accordance with the following:

(i) Loading in Vicinity of Center of Prestressed Concrete Panel Composite Slab

Lower distribution bar $\alpha=(1-0.25l/b)(1-0.8\,v/b)$ (C 4.5-1)

provided that, in case of l/b > 2.5, the value of α when l/b = 2.5 shall be used.

(ii) Loading in Vicinity of Edge of Prestressed Concrete Composite Slab

Upper distribution bar $\alpha=(1-2v/b)/8$ (C 4.5-2)

where, l : span of prestressed concrete panel composite slab
b: width of prestressed concrete panel composite slab
v: width of distribution of concentrated load

Distribution bars in a cantilevered part of a prestressed concrete panel composite slab shall be not less than 1/6 of the cross-sectional area of main tensile steels per meter of slab width per meter of slab length.

Reinforcing bars of diameter not less than 6 mm shall be arranged at the bottom of the cantilevered part at a spacing not more than 3 times the thickness of the slab in the direction perpendicular to span. However, in case of being subjected to a large concentrated load, it will be advisable to increase the quantity of these distribution bars.

With regard to 4.2, in case bending moment has been determined by a method using the generally accepted thin plate theory, drawings and tables, numerical tables, or numerical analysis method, or a method specified in standards concerning the structure under consideration, the quantity of distribution bars shall be determined in relation to the bending moment obtained by the same method.

(3) The minimum cover shall be 2.5 cm. At joints of the prestressed concrete panels, reinforcing bars inside cast-in-place concrete shall be arranged paying attention to the fact that the full thickness of the prestressed concrete panel cannot be made the cover (see Fig. C 4.4).

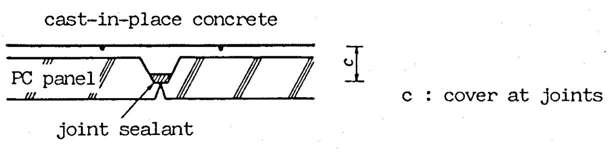


Fig. C 4.4 Concrete cover at joints of prestressed concrete panels

(4) In case a gradient exists in the prestressed concrete panel composite slab in the direction of span of the prestressed concrete panel, care shall be exercised to secure the necessary thickness of cast-in-place concrete (see Fig. C 4.5).

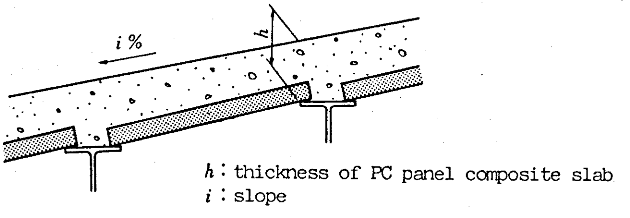


Fig. C 4.5 Thickness of prestressed concrete panel composite slab in case a gradient exists

CHAPTER 5 DESIGN OF PRESTRESSED CONCRETE PANEL COMPOSITE SLAB AS GIRDER

5.1 General

This chapter shall apply to prestressed concrete panel composite slabs comprising parts of girders.

(Comments)

This chapter discusses only design in case of using prestressed concrete panel composite slabs for the socalled flange portion making up a part of a girder, and no stipulations are made in particular regarding design of the so-called girder proper supporting the prestressed concrete panel composite slab.

This chapter may be applied to either concrete girders or steel girders as the girders supporting the prestressed concrete panel composite slab, and to either a composite structure or a non-composite structure of girders and prestressed concrete panel composite slab. Consequently, the structural form would be selected from among these combinations, and when making the selection, it will be advisable to consider type of structure, load conditions, and constraining conditions in construction.

Depending on the structural form selected, care must be exercised regarding differences in calculating section force, and method of examining limit state as stipulated in this chapter.

5.2 Effective Cross Section of Prestressed Concrete Panel Composite Slab

(1) Case of composite girder

(i) The effective cross section of a prestressed concrete panel composite slab resisting section force as the flange portion of a composite girder shall in principle be only the cast-in-place concrete portion.

(ii) The effective cross section of the prestressed concrete panel composite slab used for calculating the indeterminate forces and strains prodused by creep, drying shrinkage, and temperature difference of prestressed concrete composite slab and girder shall be the full cross section.

(iii) The effective width as a compression flange in a composite girder with a concrete girder may generally be calculated adapting the specifications for T-beams under 13.2.3 in the Design Volume of the "Standard Specifications for Concrete."

(iv) The effective width as a compression flange in a composite girder with a steel girder shall be assumed as suited.

(2) Case of non-composite girder

Design of a girder may generally be done ignoring the prestressed concrete panel composite slab.

(Comments)

(1) Prestressed concrete panels in a prestressed concrete panel composite slab will have joints in a direction perpendicular to the span of the girder and the cross sections decrease at the joints. Giving consideration to this point, it

was decided to ignore the prestressed concrete panel as a rule not only in the case of being subjected to tensile force, but also in case of being subjected to compressive force in calculating the effective cross section of the prestressed concrete panel composite slab resisting section force. However, in case the contribution of the prestressed concrete panel has been confirmed through experiments and performances, the effective cross section of the prestressed concrete panel remaining after deducting the reduction in cross section at the joint may be considered limited to the case of being subjected to compressive force.

The prestressed concrete panels are discontinuous in the direction of span, but it is not that there is no contribution to indeterminate forces at all, so to be on the conservative side, the prestressed concrete panel was included in the effective cross section in calculation of indeterminate force produced by creep, drying shrinkage, and temperature differential of the prestressed concrete panel composite slab and the girder.

Effective compression flange width of composite girders with concrete girders may be determined in accordance with Eq.(C 13.2.1) or (C 13.2.2)

(i) For beams with slabs on both sides of the web,

$$b_e = b_f + l/4$$

where b_e shall not exceed the distance between the center lines of slabs on both sides.

(ii) For beams with a slab on one side of the web only,

$$b_e = b_f + b_1 + l/8$$

where b_e shall not exceed the sum of b_1, b_f and 1/2 the clear span length of the slab.

In the above computations, l shall be taken as the span length for a simply supported beam, the distance between points of inflection for a continuous beam, or twice the clear span length for a cantilever beam. the value of b_f shall be taken as width of upper flange in the concrete girder.

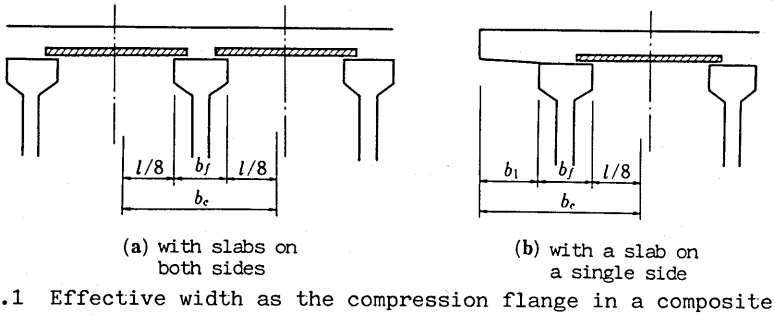


Fig. C 5.1 Effective width as the compression flange in a composite girder with concrete girders

The effective width as the compression flange in a composite girder with a steel girder, in case of application to a highway bridge, may be determined referring respectively to related specifications and standards.

(2) Considering a prestressed concrete panel composite slab and its supporting girder as lappend beams and on comparing the bending rigidities of the two, the former is generally not more than about several percent of the latter. Accordingly, it is permissible not to consider the prestressed concrete panel composite slab in the effective cross section and design based on only the girder supporting the prestressed concrete panel composite slab. However, the

dead weight of the prestressed concrete panel composite slab must not be ignored in the calculation of load.

5.3 Connector

(1) Connectors shall possess adequate load bearing capacity against shear force along with which it shall be of a structure effective in preventing upheaval of the prestressed concrete panel composite slab.

(2) It shall be standard for reinforcing bars to be used as connectors in case of concrete girders and studs in case of steel girders.

(3) In case of computing the shear force acting on connectors, the effective cross section of the prestressed concrete panel composite slab shall be considereed as the full cross section including the prestressed concrete panel.

(4) The clear spacing between connector and end of prestressed concrete panel shall be not less than 4/3 times the maximum size of coarse aggregate of the cast-in-place concrete, and not more than 4 cm.

(Comments)

(3) The reasons the prestressed concrete panel which was ignored in the resisting cross section as a girder is considered in case of computing shear force acting on the connector are that the prestressed concrete panel contributes somewhat to the resisting cross section and that considering it will be on the safe side.

(4) The minimum value of clear spacing was specified giving consideration to assurance that concrete will be placed between connector and prestressed concrete panel, and the maximum value considering a seating length of the prestressed concrete panel that the installed panel will not fall off.

Furthermore, computations of shear force acting on the connector and the strength of the connector, and the method of positioning the connector are to be in consideration of past studies and performances, For example, the stipulations concerning composite girders in highway bridge specifications are as follows:

1) The combination of design load used for designing connectors shall be selected in a manner that shear force between girder and deck slab will be a maximum. However, in case of a concrete girder, 1/2 of the load acting before composition, and load acting only after composition shall be considered. As for the case of a steel girder, the load acting only after composition shall be considered.

2) The shear stress intensity when design load is acting at the contact plane between deck slab and concrete shall be not more than the value given in Table C 5.1.

Table C 5.1 Permissible shearing stress at a contact plane between deck slab and concrete girders (kgf/cm^2)

	Ratio of area of sliding stopper to one of contact plane		
	1% less	from 1% to 2%	2% more
Permissible shearing stress	5	7.5	10

3) The design shear force acting on a stud shall be not more than the shear force V_a computed by Eq. (C 5.2).

$$V_a = 30 d^2 \cdot f_{ck}'^{1/2} \quad (H/d \geqq 5.5) \qquad \text{(C 5.2-1)}$$

$$= 5.5 d \cdot H \cdot f_{ck}'^{1/2} \quad (H/d < 5.5) \qquad \text{(C 5.2-2)}$$

where, H: total height of stud with about 15 cm as standard (cm)
d: axial diameter of stud (cm)
f_{ck}': specified strength of cast-in-place concrete of deck slab (kgf/cm^2)

4) In case of a steel girder, the shear force produced by drying shrinkage of the deck slab concrete and the temperature differential between deck slab and steel girder shall be borne by connectors existing in the range of girder spacing (1/10 of span when girder spacing is larger than 1/10 of girder span) at the free end of the deck slab.

5) In case of a concrete girder, the diameter of a connector reinforcing bar shall be not less than 13 mm, and the center-to-center spacing between connector reinforcing bars not less than 10 cm and not more than 50 cm. The quantity of connector reinforcing bars shall be not less than 0.2 percent of the contact area between deck slab and concrete.

6) The maximum spacing between studs shall be 3 times the thickness of the deck slab and not more than 60 cm. The minimum center-to-center spacing in the direction of the bridge axis shall be 5 d or 10 cm, and the minimum center-to-center spacing in the direction perpendicular to the bridge axis shall be d + 3.0 cm, where d is axial diameter of stud.

5.4 Slab Anchor

(1) In case of a non-composite girder, slab anchors shall be provided to prevent movement and upheaval of the prestressed concrete panel composite slab.

(2) As slab anchors, it shall be standard for reinforcing bars to be used in case of a concrete girder and studs in case of a steel girder to facilitate installation of prestressed concrete panels.

(3) The clear spacing between a slab anchor and the end of the prestressed concrete panel shall be not less than 4/3 times the maximum size of coarse aggregate of the cast-in-place concrete, and not more than 4 cm.

(Comments)

(1) It is desirable for about one slab anchor to be provided per meter. If many slab anchors are provided, composite action of the prestressed concrete panel composite slab and its supporting girders will be produced, for behavior differing from that assumed in design, and problems such as occurrence of cracking may arise.

(3) Refer to the Comment of 5.3(4).

5.5 Structural Details

(1) In case of action of tensile force on the prestressed concrete panel composite slab as the flange of a composite girder, reinforcing bars in a

quantity at least 2 percent of the total cross-sectional area of the prestressed concrete panel composite slab shall be arranged in the cast-in-place concrete in the direction of the bridge axis. Distribution bars provided in the cast-in-place concrete for the composite slab may be considered as part of the reinforcing bars in the direction of the bridge axis.

(2) Reinforcing bars shall be provided at a part where shear force is concentrated such as the vicinity of a sliding stopper.

(3) In consideration of installation of prestressed concrete panels, it is desirable for the width of the top flange of a girder supporting the prestressed concrete panel composite slab to be maintained constant, and the thickness of the top flange varied at the web side. The width of the top flange of the girder shall be decided giving consideration to the length of the prestressed concrete panel and the seating length of the panel, as well as the positions of sliding stoppers.

(4) In case the girder supporting the prestressed concrete panel composite slab is a steel girder, and high-tension bolts or rivets are used for connections of the girder, a plate for installing the prestressed concrete panel such as shown in Fig. 5.1 shall be provided at the field joint of the top flange of the girder. The plate shall have a width of 7 cm and be of the same thickness and quality as the top flange.

In case of using welded joints for connections of the steel girder, measures shall be taken in order that deformation due to welding will not occur.

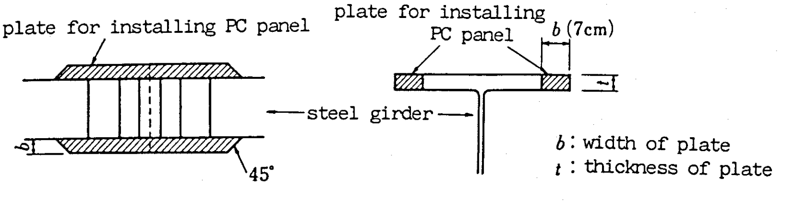


Fig. 5.1 Plate for installing a prestressed concrete panel

(Comments)

(3) When fabrication and installation of the prestressed concrete panel are considered, it will be desirable for panel length to be unified and the widths of top flanges of girders supporting the prestressed concrete panel composite slab to be made constant for all girders.

That the thickness of the top flange of the girder was varied on the side of the web is for the sake of avoiding occurrence of local stresses due to height differentials at the part supporting the panel, and not only to make installation of the panel easier.

(4) In connecting steel girders on the job, and in case of using high-tension bolts or rivets, laying of prestressed concrete panels will become difficult because of contact of fishplates and heads of high-tension bolts and rivets with the joints of top flanges of the steel girders. Therefore, it was stipulated that plates for installing prestressed concrete panels should be provided, and further, that the ends of the panels be cut somewhat to make installation easier.

When there is deformation accompanying welding, since there will be risk of height differentials occurring at the top flanges at joints of steel girders, and local stresses being produced at the supports of prestressed concrete panels, measures must be taken so that deformation will not occur. In case of applying a prestressed concrete panel composite slab to a highway bridge and using welded joints for connections of steel girders supporting the slab, the stipulations concerning welded joints in Part II. Steel Bridges, of the Highway Bridge Specifications may be used as reference.

CHAPTER 6 CONSTRUCTION

6.1 Fabrication of Prestressed Concrete Panel

6.1.1 Arrangement of Steel

(1) Steel shall be correctly positioned at the location and in the direction specified.

(2) Before positioning, loose rust, oils, and other foreign matter liable to be harmful to bond shall be removed from steel.

(Comments)

(1) Since a prestressed concrete panel is a comparatively thin member, the influence of errors in placement of steel will be great. Therefore, steel must be positioned at the correct locations and assembled sufficiently securely so as not to move when placing concrete. When positioning prestressing tendons, there will be a risk of the stress conditions of the prestressed concrete panel due to prestressing being greatly different from the stress condition considered in design if the error in the direction of height is large, so that it will be necessary for special care to be exercised in positioning of tendons.

In order to correctly position tendons, the general practice is to accurately fabricate bulkheads for tendons to be passed through and to use these bulkheads as supports for tendons.

(2) When foreign matter is adhered to steel, there will be a risk of bond with concrete being lowered. The prestressed concrete panels considered in these Recommendations are mostly of comparatively short length in general and there will be cases when impairment of bonding properties will greatly affect the properties of the prestressed concrete panels, so that special care will be needed.

6.1.2 Formwork

Formwork shall possess the required strength and rigidity, and be of such nature that the configuration, dimensions, and degree of flatness of the bottom surface of the prestressed concrete panel fabricated will be accurately secured and concrete possessing the required performance will be obtained.

(Comment)

Since good appearance, straightness of side surfaces, perpendicularity of end surfaces, and flatness of bottom surface will be especially demanded of a prestressed concrete panel, it is advisable generally to use steel forms.

6.1.3 Placing of Concrete

In placing concrete, vibrators shall be used and the entire surface of the panel thoroughly consolidated.

6.1.4 Surface Finishing

(1) The top surface of the prestressed concrete panel in which placement of

concrete has been completed shall first be levelled horizontal and suitable furrows provided.

(2) In general, the furrows shall be in the direction of the prestressing tendons with their spacings in a range of 40 to 50 mm, the height differences between ridges and depressions being about 4 mm.

(Comments)

(1),(2) It was decided that furrows should be provided at the top surface of the prestressed concrete panel to resist shear force produced at the construction joint with cast-in-place concrete. Further, in aiming for integration of old and new concrete at the construction joint, it is desirable for the surfaces of the furrows not to be smooth, but roughened (see Comment 1.1(2)).

6.1.5 Curing

(1) After placement, concrete shall be thoroughly cured maintaining the temperature and thermal conditions required for hardening, and in a manner that effects of injurious actions will not be suffered.

(2) In case of performing high-temperature accelerated curing, an ample time interval shall be provided after placing concrete until start of heating, abrupt rises in concrete temperature during heating avoided, and abrupt temperature drops during cooling avoided.

6.1.6 Prestressing

(1) The tensile force to be initially applied to a prestressing tendon shall be of the specified value taking into consideration slipping of the anchoring device, relaxation of the tendon when performing high-temperature accelerated curing, etc.

(2) The tensile force to be applied to a prestressing tendons shall be measured by the indication of the load gauge and the elongation or amount of pull-out of the tendon. The difference between the tensile force of the tendon estimated from the indication of the load gauge and the tensile force of the tendon estimated from elongation or pull-out of the tendon shall be within ±5 percent.

(3) When transferring prestress, the anchoring device shall be loosened gradually so that tendons will be uniformly relaxed.

(4) The compressive strength of concrete for transferring prestress shall not be less than 350 kgf/cm^2.

(Comment)

(4) The reason the compressive strength of concrete when transferring prestress was specified as 350 kgf/cm^2 was the consideration of the necessity for adequate bond strength between prestressing tendons and concrete.

6.1.7 Lifting Device

(1) Lifting devices shall be fabricated of the material specified under 2.1.4(3), and shall posses ample strength against the weight of the prestressed

concrete panel.

(2) Lifting devices shall be inserted adequately in the prestressed concrete panel within limits of satisfying the requirements concerning cover by concrete, and moreover, shall be positioned at the four corners of the panel.

(Comment)

Lifting devices are of insertion type, wire type, ring-shaped bar type, etc., and care must be exercised when positioning in a prestressed concrete panel so that the surface finish of the panel will not be disturbed. It would be convenient if an insertion type lifting device of the kind shown in Fig. C 6.1 were to be used.

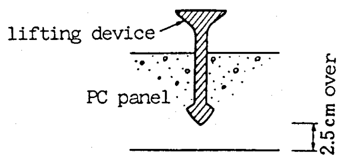


Fig. C 6.1 Lifting device of insertion type

6.1.8 Handling and Storage of Prestressed Concrete Panel

(1) In handling prestressed concrete panels, care shall be exercised not to inflict injurious effects on the panels.

(2) When temporarily storing prestressed concrete panels, care shall be exercised not to damage the panels, and supports shall be laid horizontally at the two ends of each panel in a manner that the bottom surface of the panel will not be in direct contact with the ground and that the panel will not be twisted.

(3) In case of storing prestressed concrete panels in stacked form, supports shall be provided accurately at the specified locations within 1/10 of panel length from the panel ends, with the number of panels stacked to be not more than ten, preventing deformation from being accelerated.

6.2 Transportation and Setting of Prestressed Concrete Panel

6.2.1 Transportation of Prestressed Concrete Panel

(1) Attention shall be paid to safety in transportation of prestressed concrete panels, and transporting shall be done by a method which will not inflict damage to panels.

(2) In unloading, care shall be exercised not to damage prestressed concrete panels, and in case of temporary storage, the panels shall be placed on supports as stipulated in 6.1.8(2) and (3).

6.2.2 Setting of Prestressed Concrete Panel

(1) Prestressed concrete panels shall be set correctly at the locations shown in

the design drawings by gantry crane, universal crane, truck-mounted crane, or similar equipment.

(2) Prestressed concrete slabs shall be set butted together.

(3) Setting of prestressed shall be done sequentially from the planned location in the direction of the bridge axis, and at a place where less than the width of a panel remains for adjustment, a filler panel shall be inserted.

(4) In case the width of the part for adjustment is less than 50 cm, adjustment shall be done with two or more prestressed concrete panels so that the width of one panel will not be less than 50 cm.

(5) Care shall be exercised that the surface of a prestressed concrete panel will not be soiled by dirt, oil, form releasing agent, etc.

(6) Heavy articles exceeding 500 kgf in weight per panel 1 m in width shall not be temporarily placed on a precast concrete panel that has been set.

(7) Openings may be provided in prestressed concrete panels such as for drainage pipes, cables, piping for concrete placement by pump, etc. In such case, openings shall be provided in a manner that they will not be concentrated at a single panel, and shall be made where section forces in panels are small. Two openings shall be the limit, with the sum of opening diameters not more than 30 cm and the distance from an edge of the panel to the edge of an opening not less than 20 cm. However, in case of a prestressed concrete panel of width less than 1 m, the limit shall be one opening with the opening not more than 10 cm in diameter, while the distance from an edge of the precast concrete panel to the edge of the opening shall be not less than 20 cm (see Fig. 6.1).

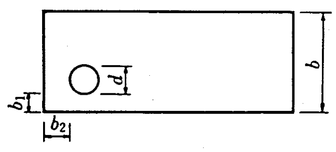


Fig. 6.1 Openings in a prestressed concrete panel

(8) In construction of the floor slab of a structure not at right angles, a prestressed concrete panel may be cut diagonally into trapezoidal shape within the range shown in Fig. 6.2 and installed. However, no opening shall be made in a prestressed concrete panel of trapezoidal shape.

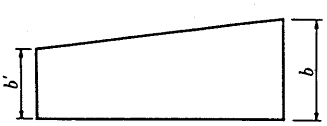


Fig. 6.2 Diagonal cutting in a prestressed concrete panel

(9) In case the portion of a prestressed concrete panel where an opening or cut

has been made is not covered by cast-in-place concrete, that portion shall be covered with epoxy resin or an equivalent material.

(10) Cast-in-place concrete in the vicinity of an opening or diagonal cut of a prestressed concrete panel shall be thoroughly reinforced.

(Comments)

(7) When an opening is made in a prestressed concrete panel, prestressing tendons will be cut and prestress will be lost from the vicinity of the opening. Therefore, consideration should be given not to concentrate openings in a single panel and to provide openings at parts where the moments acting are small, along with which the dimensions of openings must be kept to necessary minimums.

Considering that the reduction in strength of a prestressed concrete panel due to an opening is to be held to about 30 percent, the limit to opening size was held to 30 cm in a panel of the standard width of 1 m. In the pumping concrete method, the diameter of the pipeline used when placing concrete is generally about 10 cm, and an opening size of 30 cm is ample even when pipe connections are considered.

(8) For slabs which are skewed or have planar alignments, there are cases when the matter cannot be dealt with by only prestressed concrete panels of rectangular shape. the trapezoidal portions in Fig. C 6.2 that are hatched may be constructed with concrete cast in situ on adequately reinforcing with steel, but there is also the method of fabricating the prestressed concrete panel in trapezoidal shape and setting. A limit was provided to the case of cutting diagonally in order to hold strength reduction of the prestressed concrete panel to about 30 percent when fabricating into trapezoidal shape.

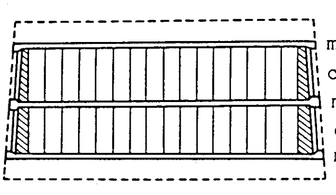


Fig. C 6.2 Setting of prestressed concrete panel in trapezoidal shape

(9) When a prestressed concrete panel has been provided with an opening or is cut there are cases in which prestressing tendons and reinforcing bars in the panel will be exposed at the surface or cover cannot be secured so that it is necessary to shut off outside air by covering with a material such as epoxy resin to prevent corrosion of prestressing steel and reinforcing bars.

6.2.3 Joint Filler

(1) In case of setting prestressed concrete panels on a steel bearing surface, a joint filler stipulated under 2.1.4(1) shall be laid at the specified location on the steel bearing surface, upon which the prestressed concrete panels shall be set.

(2) In case of setting prestressed concrete panels on a concrete bearing surface, joint filler shall be laid on the end portion of the prestressed concrete panel bearing surface, with non-shrink mortar filled in at the back,

upon which the panels shall be placed. Joint filler and non-shrink mortar as specified under 2.1.4(1) shall be used.

(Comment)

The purposes of using a joint filler is to improve contact between prestressed concrete panel and its bearing surface, and to prevent leakage of mortar from the contact portion between panel and bearing surface during placement of cast-in-place concrete. Attaching joint filler as shown in Fig. C 6.3 will be a good method.

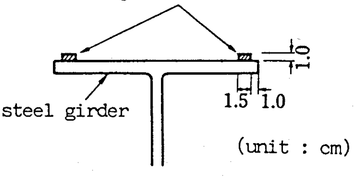


Fig. C 6.3 Attaching joint filler

(1) At connections of steel girders supporting the prestressed concrete panel composite slab, there will be cases when close contact between panel and bearing surface is difficult to achieve because of such factors as partial cut-aways of prestressed concrete panel, gradients in the span and perpendicular directions of panel, and construction errors of plates for setting panels, etc. Accordingly, special care must be taken regarding selection of the material and configuration and dimensions of joint filler used at joints of steel girders, and the method of applying the joint filler so that gaps will not occur. See 5.5(4) regarding joints of steel girders.

6.2.4 Joints

(1) Joint sealant specified under 2.1.4(2) shall be used at joints of prestressed concrete panels.

(2) In case of using non-shrink mortar as the joint sealant, thickness at the joint of 15 mm shall be standard.

(3) The surface of the non-shrink mortar filled in the joint shall be leveled horizontal, and finished to a rough surface.

(Comment)

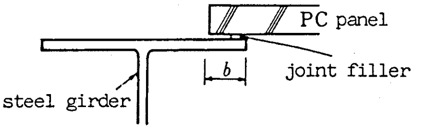
(3) The reason the joint is to be finished to a rough surface is that it is aimed to improve bond strength with cast-in-place concrete, and in general, a broomed finish will be acceptable.

6.2.5 Painting of Steel Bearing Surface

In view of the risk of rusting occurring at contact portions between steel bearing surfaces and prestressed concrete panel, rust preventive painting shall be performed prior to setting of prestressed concrete panels.

(Comment)

Painting is to be done to prevent rusting since the steel bearing surface has only the prestressed concrete panel in contact with it. In general, treatment of the extent of applying 2 coats of tar epoxy resin will be adequate. The area to be painted is shown in Fig. C 6.4.



b = seating length of PC panel + 1 cm : painting width

Fig. C 6.4 Painting area at steel bearing surface

6.3 Construction of Prestressed Concrete Panel Composite Slab

6.3.1 Preparation before Placement of Cast-in-Place Concrete

(1) In placement of cast-in-place concrete, water shall be thoroughly sprinkled prior to placement in order that the surface of the prestressed concrete panel laid out will be in a moist condition.

(2) The compressive strength of the concrete in the prestressed concrete panel when cast-in-place concrete is placed shall be not less than 500 kgf/cm^2.

(Comment)

(2) If it has been confirmed that the compressive strength of concrete in the prestressed concrete panel is not less than 500 kgf/cm^2 when shipping out panels from the factory, there will be no necessity for concrete of compressive strength to be done on the job.

6.3.2 Construction of Cast-in-Place Concrete

Placing, curing, and surface finishing of cast-in-place concrete shall be done in accordance with the Construction Volume of the "Standard Specifications for Concrete."

CHAPTER 7 TESTING AND INSPECTION

7.1 Testing and Inspection of Concrete

7.1.1 Testing of Concrete

(1) Before starting construction, tests of the materials required and tests to select mix proportions for concrete shall be performed, along with which the performances of machinery and equipment shall be ascertained.

(2) Compressive strength tests of concrete used for prestressed concrete panels shall be performed twice: at the time of prestressing and at 28-day age.

(3) Compressive strength tests of cast-in-place concrete shall be performed at 28-day age.

7.1.2 Quality Inspection of Concrete

Quality inspections of concrete shall be made adapting, 13.4 in the Construction Volume of the "Standard Specifications for Concrete."

(Comments)

Quality inspections of concrete are to be made as follows adapting 13.4 in the Construction Volume of the "Standard Specifications for Concrete":

(1) If the probability of test values of compressive strength obtained with cylinder specimens being not more than 5 percent below the specified concrete strength can be estimated with a suitable risk factor, it may be considered that the concrete possesses the required quality. In this case, all of the test values obtained and a part of consecutive test values are to be considered as one set and inspected. One test value is to be the average value of 3 specimens made from the same sample.

(2) In case it is judged that the quality of concrete is unsuitable as a result of inspection, appropriate measures shall be taken such as modification of mix proportions, inspection of machinery and equipment performances, and improvement in operating methods, along with which it shall be ascertained whether the concrete that has been placed can achieve the required objective and a suitable measure shall be provided as necessary.

7.2 Testing of Steel

(1) Reinforcing bars shall be tested before using to ascertain quality. In principle, tests shall be in accordance with methods specified in JIS G 3112, "Steel Bars for Concrete Reinforcement," or when using rerolled bars, in JIS G 3117, "Rerolled Steel Bars for Concrete Reinforcement."

(2) Prestressing steel shall be tested before using to ascertain quality. In principle, tests shall be in accordance with methods specified in JIS G 3536, "Uncoated Stress-Relieved Steel Wire and Strand for Prestressed Concrete."

7.3 Testing and Inspection of Prestressed Concrete Panel

7.3.1 Quality Inspection of Prestressed Concrete Panel

(1) In manufacture of prestressed concrete panels, quality inspections shall be made on the panels.

(2) Bending strength tests of prestressed concrete slabs shall be performed adapting the method of testing bending strength in JIS A 5313, "Prestressed Concrete Beams for Slab Bridges." The tests shall be performed after compressive strengths of cylinder specimens cured under identical conditions as the product have reached 500 kgf/cm^2, or after 28-day age.

(3) Cracks shall not occur in a prestressed concrete panel when breaking test moment has been applied in accordance with the test specified in (2) above. Breaking test moment shall be computed by the value at which the increment in stress intensity due to bending moment at the bottom fiber of the prestressed concrete panel will be the "absolute value of effective prestress at the bottom fiber of prestressed concrete panel + 30 kgf/cm^2." The breaking test moment shall be made to act in a manner that the side of the prestressed concrete panel contact surface with the cast-in-place concrete will be the compression zone.

(4) The quality inspection by bending strength tests shall be performed sampling one panel from any manufacturing line of a single set, and one panel from another line, a total of two panels, and carrying out the bending strength tests stipulated under (2). The testing shall be as follows:

If both panels conform with the requirements of (3), the entire number in that set shall be considered as acceptable. In the event even one of the two does not conform with the requirements, one panel each shall be sampled from four other manufacturing lines of that set, and bending strength tests performed.

(i) If all four panels conform with the requirements of (3), all manufacturing lines except that from which the unsatisfactory panel was sampled shall be considered acceptable. The manufacturing line from which the unsatisfactory panel was obtained shall have two more panels sampled, and if both are satisfactory, all of that manufacturing line except the unsatisfactory panel shall be considered acceptable. In case even one of the two panels is unsatisfactory, bending strength tests shall be performed on all of the panels in that manufacturing line.

(ii) In case even one of the four panels does not meet the requirements of (3), bending strength tests shall be performed on all of the remainder of the set. In principle, one set shall consist of ten manufacturing lines.

7.3.2 Outward Appearance, Configuration, and Dimensions of Prestressed Concrete Panel

(1) In manufacturing prestressed concrete panels, inspections shall be made of outward appearance, configuration, and dimensions.

(2) A prestressed concrete panel shall be of good appearance and not have defects such as injurious blemishes, cracks, and twisting.

(3) The top surface of the prestressed concrete panel shall have not less than 20 and not more than 25 furrows per meter in the direction of placement of prestressing tendons.

(4) The tolerances in dimensions of prestressed concrete panels shall be the values given in Table 7.1.

Table 7.1 Tolerances in dimensions of prestressed concrete panel

Division	Tolerance
Length	±10mm
Width	+5mm ~ -3mm
Thickness	+5mm ~ -2mm
Straightness of side surface	±3mm
Perpendicularity of end surface	±10mm

(5) Inspection of outward appearance, configuration and dimensions shall be performed as follows sampling one panel from any manufacturing line and one panel from another line out of one set, and ascertaining that they conform with the stipulations of (1), (2), and (3) as follows:

If both panels conform with the stipulations, all of the panels in that set shall be considered as acceptable. In the event even one of the two does not conform with the requirements, one panel each shall be sampled from four other manufacturing lines of that set, and it shall be confirmed that they conform with the requirements of (1), (2), and (3).

(i) If all four panels conform with the requirements, all manufacturing lines except that from which the unsatisfactory panel was sampled shall be considered acceptable. The manufacturing line from which the unsatisfactory panel was obtained shall have two more panels sampled, and if both are satisfactory, all of that manufacturing line except the unsatisfactory panel shall be considered acceptable. In case even one of the two panels is unsatisfactory, inspections shall be carried out on all of the panels in that manufacturing line.

(ii) In case even one of the four panels does not meet the requirements, inspections shall be carried out on all of the remainder of the set.

In principle, one set shall consist of ten manufacturing lines.

(Comments)

(3) The top surface of a prestressed concrete panel will have furrows at spacings of 40 to 50 mm in accordance with 1.1(2)(v) and 6.1.4(2), meaning that there will be 20 to 25 furrows per meter in the direction of prestressing tendon arrangement, in effect, the direction of length of the panel.

(4) The thickness of a prestressed concrete panel is to be measured at the ridge of a furrow which is easier for making measurements. Since there are furrows in the top surface of the prestressed concrete panel in accordance with 1.1(2)(v) and 6.1.4(2), and the height difference between ridge and bottom of a furrow is about 4 mm, the thickness of the prestressed concrete panel as measured at the ridge is about 2 mm more than the average thickness. In case of a prestressed concrete panel with furrows of other shapes the thickness is to be measured by some other suitable method.

The straightness of the side surface of a prestressed concrete panel is necessary for preventing leakage of mortar from gaps at the joints between panels. The straightness of the side surface of the prestressed concrete panel is measured by the deviation from a straight line connecting the two ends of a side surface of the panel, and this deviation must be within ±3 mm at all points on the side surface.

The perpendicularity of an end surface of a prestressed concrete panel is a stipulation for the purpose of securing the seating length of the panel with the required precision. This perpendicularity is specified by the distance from a line extending in a direction orthogonal to the side surface from one edge of an end surface to the other end, and this must be within ±10 mm.

7.4 Testing and Inspection of Joint Sealant

(1) In principle, expansion tests and compressive strength tests shall be performed on non-shrink mortar to be used as joint sealant before using.

(2) The expansion test shall be in accordance with the Japan Society of Civil Engineers standard, "Method of Testing Expansion of Filler Mortar Containing an Expansive Agent."

(3) Compressive strength tests shall be in accordance with JIS A 1108, "Method of Test for Compressive Strength of Concrete."

(4) In case shrinkage is not recognizable at the specified date in expansion tests, it may be considered that the non-shrink mortar possesses the required quality.

(5) In the event the test values in compressive strength tests are not lower than the specified strength of corresponding cast-in-place concrete, it may be considered that the non-shrink mortar possesses the required quality. In general, the tests shall be performed at the age of 28 days.

(Comments)

(1) In case of using premixed type non-shrink mortar and the manufacturer has carried out tests beforehand and it has been confirmed that the requirements of (4) and (5) are satisfied, these tests may be omitted.

(4) In general, 7 days may be considered as the age at which shrinkage must not be indicated in expansion tests.