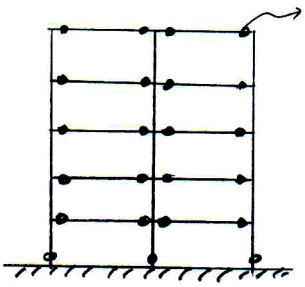
EQ Design of RC Structures

3 Types of RC structures according to ductility capacity

- ordinary frame — low ductility
- intermediate frame — intermediate ductility
- Special frame — high ductility

Basic Requirements of special frame and intermediate frame

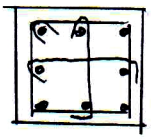
1) plastic hinge distribution

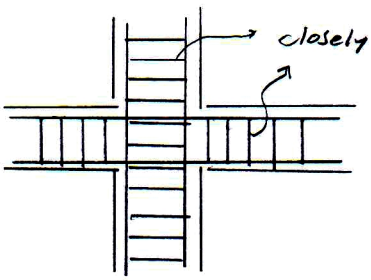


plastic hinges in beams

strong column – weak beam

2) Ductility details



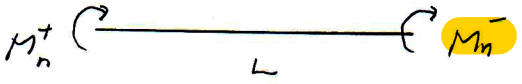


closely spaced hoops at plastic hinge zone

3) prevent brittle shear failure

shear force demand is calculated based on the flexural capacity

shear strength > the shear demand



$$V_u = \frac{|M_n^+| + |M_n^-|}{L}$$

0520 Special Provisions for Seismic Design

0520 내진설계시 특별 고려사항

0520.1 General

0520.1.1 Scope

0520.1.1.1 Monolithic structures

Provisions of this 0520 specify the special requirements for seismic design and detailing of reinforced concrete members, and shall apply only to monolithic reinforced concrete structures resisting forces induced by earthquake motions.

0520.1.1.2 Structures other than monolithic structures

When provisions of this 0520 apply to prefabricated structures other than monolithic structures, the provisions shall be modified based on appropriate physical evidence and analysis, and special seismic design for these structures shall satisfy the corresponding provisions.

0520.1.1.3 Precast and prestressed concrete structures

Precast and prestressed concrete structures shall be permitted to be considered as earthquake-resistant structures only if they satisfy the safety and serviceability requirements for monolithic structures.

0520.1.1.4 Exceptions

A reinforced concrete structural system not satisfying this 0520 shall be permitted to be used if it is demonstrated by experimental evidence or analysis that the proposed system satisfies the requirements of this 0520 or has the structural performance equal to or exceeding that required by this 0520.

0520.1 일반사항

0520.1.1 적용범위

0520.1.1.1 일체식 구조물

이 절의 규정은 철근콘크리트부재의 내진설계 및 상세 규정에 대한 특별사항을 규정하고 있으며, 지진운동에 의해 발생된 하중에 저항하는 일체식 철근콘크리트 골조에만 적용하여야한다.

0520.1.1.2 일체식 구조물이 아닌 구조물

일체식 구조물과 다른 조립식 구조물의 경우 이 규정을 적용하여야 할 때는 적절한 물리적 증거와 해석에 따라 수정되어야하며, 구조물에 따른 특별내진설계는 해당 기준을 만족하여야한다.

0520.1.1.3 프리캐스트 및 프리스트레스트 콘크리트 구조물

프리캐스트 및 프리스트레스트 콘크리트 구조물은 일체식 구조물에서 요구되는 안전성 및 사용성에 관한 조건을 갖추고 있는 경우에 한하여 내진구조로 다룰 수 있다.

0520.1.1.4 예외규정

이 절에서 요구하는 사항을 만족하지 못하는 철근콘크리트구조 형식의 경우 실험이나 해석에 의해 이 절에서 요구하는 사항을 만족하거나 그 이상의 구조성능을 갖는 것이 증명된다면 이를 사용할 수 있다.

0520.1.2 Requirements for seismic-force-resisting systems

(1) This 0520 specifies the requirements for design and construction of reinforced concrete members subjected to design earthquake forces that are determined based on the energy dissipation capacity in the nonlinear range of response to earthquake motions.

(2) For other than the provisions of this 0520, the provisions of 0501 to 0519 specified in this chapter shall be applied.

(3) When the design earthquake load is determined for ordinary or intermediate moment frames as the seismic-force-resisting system, the requirements of this 0520 for ordinary or intermediate moment frames shall be satisfied.

(4) When the design earthquake load is determined for special moment frames forming part of the seismic-force-resisting system, the requirements of this 0520 for special moment frames shall be satisfied.

(5) A reinforced concrete structural system not satisfying this 0520 shall be permitted to be used as the earthquake-resistant system if it is demonstrated by experimental evidence and analysis that the proposed system has strength and toughness equal to or exceeding those required by this 0520.

(6) Vibration isolation and damping devices, which are designed and demonstrated by professional structural engineers in accordance with 0306.12 or 0306.13, shall be permitted to be used to decrease the vibration of structures.

0520.1.2 지진력저항시스템별 요구사항

(1) 이 절은 지진하중과 관련하여 비선형거동 범위 내에서 에너지소산에 근거하여 결정된 설계하중을 받는 철근콘크리트 부재의 설계 및 시공에 대한 요구사항을 규정하고 있다.

(2) 이 절 규정 이외의 사항은 이 기준의 0501부터 0519까지의 규정을 적용하여야한다.

(3) 지진력저항시스템을 보통 또는 중간 모멘트 골조시스템으로 선택하여 설계지진하중을 산정하였다면, 보통 또는 중간 모멘트 시스템에 대한 이 절의 요구사항을 만족하여야한다.

(4) 지진력저항시스템을 특수구조시스템으로 선택하여 설계지진하중을 산정하였다면, 특수구조시스템에 대한 이 절의 요구사항을 만족하여야한다.

(5) 이 절의 요구사항을 만족하지 않는 철근콘크리트구조시스템의 경우도 실험 혹은 해석에 따라 이 절에서 요구하는 충분한 강도와 인성을 보유하는 것으로 입증된다면 내진시스템으로 허용할 수 있다.

(6) 구조물의 진동을 감소시키기 위하여 0306.12 또는 0306.13의 규정에 따라 관련 구조전문가에 의해 설계되고 그 성능이 검증된 면진 및 진동감쇠장치를 사용할 수 있다.

0520.1.3 Analysis and design of structural members

0520.1.3.1 Lateral-force-resisting Systems

Interaction of all structural and nonstructural

0520.1.3 구조부재의 해석과 설계

0520.1.3.1 횡력저항시스템

지반운동에 대하여 구조부재를 해석할 때, 구조

members, which affects linear and nonlinear responses of structures in terms of materials, shall be considered in the analysis of structural members for earthquake motions.

물의 재료적인 측면에서 선형 및 비선형 응답에 영향을 주는 모든 구조 및 비구조 부재의 상호작용을 고려하여야한다.

EQ load Combination

U = 1.4D

U = 1.2D + 1.6L

U = 1.2D + 1.0L ± 1.0E

U = 0.9D ± 1.0E

0520.1.3.2 Nonstructural members

Rigid members assumed not to be a part of the lateral-force-resisting system shall be permitted to be used if their effects on the response of the structural system are considered. Effects of failure of structural and nonstructural members that are not a part of the lateral-force-resisting system shall also be considered.

0520.1.3.3 Structural members below base of structures

Structural members, which are below the base of structures and required to transmit forces resulting from earthquake effects to the foundation, shall satisfy the requirements of this 0520.

구조물의 밑면 아래에 있는 구조부재 중에서 지진으로 인하여 발생한 힘을 기초에 전달하는데 필요한 부재도 이 절의 요구 사항을 만족하여야 한다.

0520.1.3.4 Structural members not designated as part of lateral-force-resisting system

All structure members, which are not supposed to be a part of the lateral-force-resisting system, shall also satisfy the requirements of 0520.2.

0520.1.3.4 횡력저항시스템이 아닌 구조부재

횡력저항시스템의 일부가 아니라고 생각되는 모든 구조부재들도 0520.2의 요구사항을 만족하여야한다.

~~For special wall and frame~~

0520.1.4 Concrete of seismic-force-resisting members

0520.1.4.1 Specified compressive strength of concrete

Specified compressive strength of concrete f_{ck} shall not be less than 21 MPa.

$f_{ck} \geq 21$ MPa

For Light weight concrete,

$f_{ck} \leq 35$ MPa

Light weight aggregate is susceptible to crushing

0520.1.4.2 Specified compressive strength of lightweight concrete

Specified compressive strength of lightweight concrete shall not exceed 35 MPa. If it is dem-

onstrated by experimental evidence that structural members made with lightweight concrete have strength and toughness equal to or exceeding those of comparable members made with normal-weight concrete of the same strength, the greater compressive strength shall be permitted.

트를 사용한 구조부재가 같은 강도의 보통중량콘크리트를 사용한 부재의 강도 및 인성 이상을 갖는 것이 확인된다면, 이보다 큰 압축강도를 사용할 수 있다.

0520.1.5 Reinforcement of seismic-force-resisting members

0520.1.5.1 Reinforcement used in frames or boundary elements of structural walls

Specified yield strength f_y of reinforcement (KS D 3504, 3552, 3688, 7017) used in special moment frames subjected to earthquake-induced flexural and axial forces or boundary elements of special shear walls shall not exceed 600 MPa and 500 MPa for longitudinal and transverse reinforcement, respectively, and shall satisfy the following requirements of 0520.1.5.2 and 0520.1.5.3.

For longitudinal bars,

$f_y \leq$ 600MPa (KCI)

550MPa (ACI)

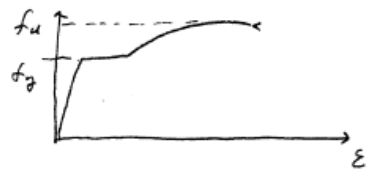
For shear reinforcement

$f_y \leq$ 500 MPa (KCI)

420 MPa (ACI)

Actual $f_y \leq f_y + 120$MPa

$f_u \geq 1.25 f_y$



- unexpected increased yield strength can cause crushing failure of concrete in compression and shear
- fracture failure of re-bars should be prevented with increased f_u.

0520.1.5.2 Actual yield strength limits

Actual yield strength based on mill tests shall not exceed the specified yield strength by more than 120 MPa. Retest shall not exceed this value by more than an additional 20 MPa.

0520.1.5.3 Actual tensile strength ratio limit

Ratio of the actual tensile strength to the actual yield strength shall not be less than 1.25.

0520.1.5.4 Mechanical splices

(1) Mechanical splices shall be permitted to be classified as Type 1 or Type 2 mechanical splices.

① Type 1 mechanical splices shall conform to 0508.6.1.

② Type 2 mechanical splices shall conform to 0508.6.1, and shall be capable of developing the specified tensile strength of

0520.1.5.4 기계적이음

(1) 기계적이음은 유형 1 또는 유형 2 기계적이음으로 분류할 수 있다.

① 유형 1 기계적이음은 0508.6.1의 규정에 따라야한다.

② 유형 2 기계적이음은 0508.6.1의 규정에 따르고, 이음철근은 규정한 인장강도를 달성할 수 있어야한다.

the spliced bar.

(2) Type 1 mechanical splices shall not be used within a distance equal to twice the member depth from the column or beam face or from sections where yielding of the reinforcement is likely to occur as a consequence of inelastic lateral displacements. Type 2 mechanical splices shall be permitted to be used at any location.

0520.1.5.5 Welded splices

(1) Welded splices of reinforcement resisting earthquake-induced forces shall conform to 0508.6.1, and also shall not be used within a distance equal to twice the member depth from the column or beam face or from sections where yielding of the reinforcement is likely to occur as a consequence of inelastic lateral displacements.

(2) Welding of stirrups, ties, inserts, or other similar elements to longitudinal reinforcement that is required by design shall not be permitted.

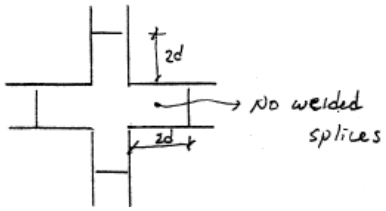
mechanical splice

Type I ⇒ Strength ≥ 1.25 f_y

Type II ⇒ Strength ≥ 1.25 f_y & f_u

Welding and Mechanical Splice TYPE I

- Welding can lead to local embrittlement of steel (poor inelastic behavior)
- increases flexural capacity, hence applied shear



(2) 요구되는 종방향 철근에 대한 스터럽, 띠철근, 삽입물 또는 이와 유사한 요소의 용접은 허용되지 않는다.

0520.2 Frame members not designated as part of seismic-force-resisting system

0520.2.1 Scope

Frame members assumed not to contribute to lateral resistance shall be designed in accordance with 0520.2.2 or 0520.2.3 depending on the magnitude of moments induced in those members when subjected to the design displacement. If effects of the design displacement are not explicitly checked, the requirements of 0520.2.3 shall be satisfied.

0520.2.2 When induced sectional forces under design displacements do not exceed design member strength

0520.2.2.1 General

0520.2 지진력에 저항하지 않는 골조부재

0520.2.1 적용범위

수평력을 받지 않는 것으로 가정한 골조부재는 설계변위가 발생할 때 부재에서 계산한 휨모멘트를 0520.2.2 또는 0520.2.3에 따라 설계하여야 한다. 만약, 설계변위에 대하여 명확한 검토를 수행하지 않을 경우에는 0520.2.3의 요구사항을 따라야 한다.

0520.2.2 설계변위 때의 단면력이 설계부재력 이내의 경우

0520.2.2.1 일반사항

Where the induced moments and shears by the combined effects of factored gravity loads and design displacements of 0520.2.1 do not exceed the design moment and shear strength of the frame member, the requirements of 0520.2.2.2, 0520.2.2.3, and 0520.2.2.4 shall be satisfied. In the case, the gravity load combinations of $1.2D + 1.0L + 0.2S$ or $0.9D$, whichever is critical, shall be used. The live load factor shall be permitted to be reduced to 0.5 for areas where L is greater than 5.0 kN/m², except for garages.

중력휨모멘트 및 전단력과 0520.2.1의 설계변위에 따라 계산된 휨모멘트와 전단력의 조합력이 골조부재의 설계휨강도와 설계전단강도를 초과하지 않을 경우에는, 다음 0520.2.2.2, 0520.2.2.3, 0520.2.2.4의 조건을 만족하여야 한다. 이 때 $1.2D + 1.0L + 0.2S$ 또는 $0.9D$의 연직조합하중 중 위험한 경우를 사용하여야 하며, 창고를 제외하고는 L이 5.0kN/m²을 초과하면, 활하중 L에 대한 하중계수는 0.5로 낮출 수 있다.

0520.2.2.2 Members with factored axial forces not exceeding $A_g f_{ck}/10$

Members with factored axial forces not exceeding $A_g f_{ck}/10$ shall satisfy 0520.4.2.1. Transverse reinforcement spacing shall not exceed $d/2$ along the length of the member.

0520.2.2.2 계수축력이 $A_g f_{ck}/10$을 초과하지 않는 부재

계수축력이 $A_g f_{ck}/10$을 초과하지 않는 부재들은 0520.4.2.1을 만족하여야 한다. 이 때 스터럽의 간격은 부재의 전 길이에 걸쳐서 $d/2$ 이하이어야 한다.

0520.2.2.3 Members with factored axial forces exceeding $A_g f_{ck}/10$

Members with factored axial forces exceeding $A_g f_{ck}/10$ shall satisfy 0520.5.3, 0520.5.4.1(3), 0520.5.4.3, and 0520.5.5. Maximum tie spacing shall be s_o for the full column height, and the spacing s_o shall not be greater than the lesser of six diameters of the smallest longitudinal bar enclosed and 150 mm.

0520.2.2.3 계수축력이 $0.1A_g f_{ck}$을 초과하는 부재

계수축력이 $0.1A_g f_{ck}$을 초과하는 부재들은 0520.5.3, 0520.5.4.1(3), 0520.5.4.3 및 0520.5.5를 만족하여야 한다. 이 때 띠철근의 최대간격은 기둥의 전 높이에 걸쳐서 s_o가 되도록 하고, 간격 s_o는 띠철근으로 둘러싸인 종방향 철근 중 가장 작은 지름의 6배 이하, 또한 150 mm 이하이어야 한다.

0520.2.2.4 Members with factored axial forces exceeding $0.35P_o$

Members with factored axial forces exceeding $0.35P_o$ shall satisfy 0520.2.2.3. Amount of transverse reinforcement shall be one-half of that required by 0520.5.4.1, and spacing shall not be greater than s_o for the full column height.

0520.2.2.4 계수축력이 $0.35P_o$를 초과하는 부재

계수축력이 $0.35P_o$를 초과하는 부재는 0520.2.2.3의 규정을 만족하여야 하며, 횡방향철근량은 0520.5.4.1에 규정된 값의 1/2 이어야 하고, 기둥의 전체 높이에 걸쳐 간격은 s_o를 초과하지 않아야 한다.

0520.2.3 When induced sectional forces under design displacements exceed design member strength

0520.2.3 설계변위 때의 단면력이 설계부재력을 초과하는 경우

0520.2.3.1 General

Where the induced moments and shears under design displacements of 0520.2.1 exceed the design moment and shear strength of the frame member, or where the induced moments are not calculated, the requirements of 0520.2.3.2, 0520.2.3.3, and 0520.2.3.4 shall be satisfied.

0520.2.3.1 일반사항

0520.2.1의 수평변위에 따라 계산된 휨모멘트 및 전단력이 골조부재의 설계휨강도 및 설계전단강도를 초과하거나, 발생되는 휨모멘트를 계산하지 않는다면 다음 0520.2.3.2, 0520.2.3.3, 0520.2.3.4의 조건을 만족하여야한다.

0520.2.3.2 Splices of reinforcement

Materials shall satisfy 0520.1.4 and 0520.1.5. Mechanical splices and welded splices shall satisfy 0520.1.5.4 and 0520.1.5.5(1), respectively.

0520.2.3.2 철근이음

재료는 0520.1.4 및 0520.1.5를 만족하여야하고, 철근의 기계적 이음은 0520.1.5.4를 만족하여야하며, 용접이음은 0520.1.5.5(1)을 만족하여야한다.

0520.2.3.3 Members with factored axial forces not exceeding $A_g f_{ck}/10$

Members with factored axial forces not exceeding $A_g f_{ck}/10$ shall satisfy 0520.4.2.1 and 0520.4.4. Transverse reinforcement spacing shall not exceed $d/2$ along the length of the member.

0520.2.3.3 계수축력이 $A_g f_{ck}/10$ 초과하지 않는 부재

계수축력이 $A_g f_{ck}/10$을 초과하지 않는 부재는 0520.4.2.1과 0520.4.4를 만족하여야한다. 이때 스터럽의 간격은 부재의 전 길이에 걸쳐서 $d/2$이하이어야한다.

0520.2.3.4 Members with factored axial forces exceeding $A_g f_{ck}/10$

Members with factored axial forces exceeding $A_g f_{ck}/10$ shall satisfy 0520.5.3.1, 0520.5.4, 0520.5.5, and 0520.6.2.1.

0520.2.3.4 계수축력이 $A_g f_{ck}/10$ 초과하는 부재

계수축력이 $A_g f_{ck}/10$을 초과하는 부재들은 0520.5.3.1, 0520.5.4, 0520.5.5, 0520.6.2.1을 만족하여야한다.

0520.2.4 Precast concrete frames

Precast concrete frame members and their connections assumed not to contribute to lateral resistance shall satisfy 0520.2.4.1, 0520.2.4.2, and 0520.2.4.3 in addition to 0520.2.1, 0520.2.2, and 0520.2.3.

0520.2.4 프리캐스트콘크리트 골조

수평력을 받지 않는다고 가정된 접합부를 포함한 프리캐스트콘크리트 골조 부재는 0520.2.1, 0520.2.2, 0520.2.3 외에도, 다음 0520.2.4.1, 0520.2.4.2, 0520.2.4.3을 만족하여야한다.

0520.2.4.1 Placement of transverse reinforcement

Transverse reinforcement specified in 0520.2.2.2 shall be provided along the entire column height, including the depth of beams

0520.2.4.1 띠철근의 배치

0520.2.2.2 에서 규정된 띠철근은 보의 깊이를 포함한 전체 기둥높이에 걸쳐서 배치하여야한다.

0520.2.4.2 Structural integrity reinforcement

0520.2.4.2 구조일체성 철근

Structural integrity reinforcement shall be provided in accordance with 0516.3.

0516.3의 규정과 같이, 구조일체성 철근이 확보되어야 한다.

0520.2.4.3 Bearing length at support of beams

Bearing length at the support of a beam shall be at least 50 mm longer than the calculated value from 0506.8 using bearing strength.

0520.2.4.3 보의 받침부의 지압길이

보의 받침부에서 지압길이는 0506.8의 지압강도를 이용한 계산에 따라 결정된 값보다 최소 50 mm 더 길게 하여야 한다.

0520.3 Requirements for intermediate moment frames

0520.3 중간모멘트골조 요구사항

0520.3.1 Scope

This section shall apply to intermediate moment frames.

0520.3.1 적용범위

0520.3.2 Classification of members for design code application

0520.3.2.1 Members with factored axial forces not exceeding $A_g f_{ck}/10$

Where factored axial forces P_u do not exceed $A_g f_{ck}/10$, reinforcement of frame members shall conform to 0520.3.4.

0520.3.2.2 Members with factored axial forces exceeding $A_g f_{ck}/10$

Where factored axial forces exceed $A_g f_{ck}/10$, reinforcement shall conform to 0520.3.5, unless spiral reinforcement is provided as specified in Eq. (0506.4.1).

0520.3.2.3 Seismic design of two-way slabs without beams

When two-way slabs without beams are considered as part of a frame resisting earthquake effects (E), reinforcement to resist the induced moments by earthquake effects shall conform to 0520.3.6 in any span.

0520.3.3 Design shear strength

0520.3.3.1 Calculation of design shear strength

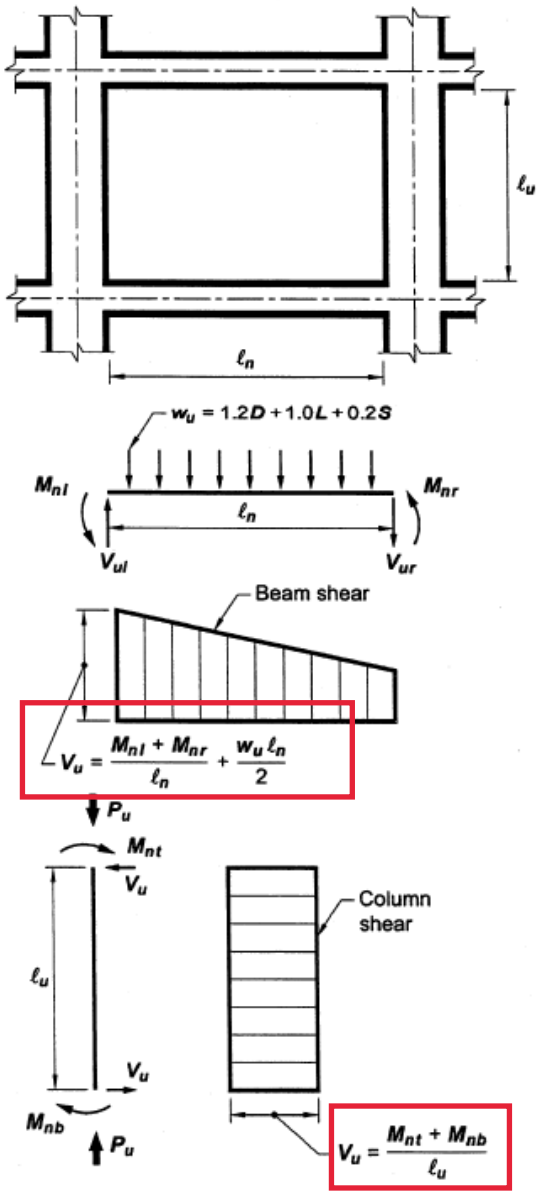


Fig. R21.3.3—Design shears for intermediate moment frames.

Design shear strength of beams, columns, and two-way slabs resisting earthquake effects shall satisfy the following (1) and (2).

(1) Design shear strength shall be at least the sum of the shear associated with development of nominal moment strengths of the member at each restrained end of the clear span and the shear calculated for factored gravity loads.

(2) Design shear strength shall not be less than the maximum shear force obtained from design load combinations including the earthquake effect, which is taken as twice that prescribed by the seismic design code.

지진에 저항하는 보, 기둥 및 2방향 슬래브의 설계전단강도는 다음 (1) 또는 (2)의 규정을 만족시켜야한다.

(1) 순경간의 각 고정단에서 부재 공칭휨강도 값에 따라 계산된 전단력과 계수 연직하중에 의한 전단력의 합 이상이어야 한다.

(2) 내진설계기준의 설계용 하중조합에서 지진하중을 2배로 하여 계산한 최대 전단력 이상이어야한다.

0520.3.4 Beams

0520.3.4.1 Flexural strength limits

At the face of the joint, the positive moment strength shall be at least one-third the negative moment strength. At any section along the length of the beam, both the negative and positive strength shall not be less than one-fifth the maximum moment strength provided at the face of either joint.

0520.3.4.2 Placement of hoops

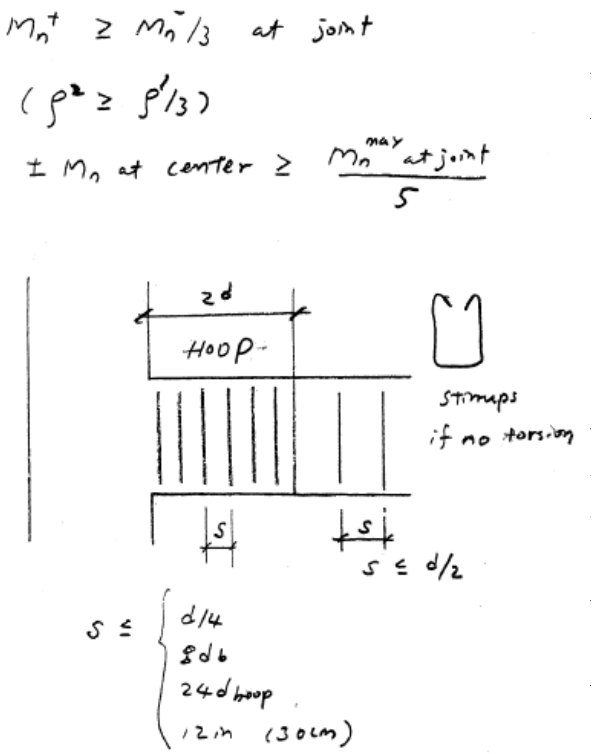
Hoops shall be provided over the length of at least two times the beam depth measured from the face of the supporting member toward the mid-span. The first hoop shall be located not more than 50 mm from the face of the supporting member. Hoop spacing shall not exceed the smallest of $d/4$, 8 times the diameter of the smallest longitudinal bar enclosed, 24 times the diameter of the hoop bar, and 300 mm.

0520.3.4.3 Placement of stirrups

Stirrup spacing shall not exceed $d/2$ along the length of the beam.

0520.3.5 Columns

0520.3.4 보



0520.3.4.3 스터럽의 배치

스터럽의 간격은 부재 전 길이에 걸쳐서 $d/2$ 이하이어야 한다.

0520.3.5 기둥

0520.3.5.1 Applicable provisions

Columns shall be spirally reinforced in accordance with 0505.5.2, or shall conform to the following 0520.3.5.2, 0520.3.5.3, and 0520.3.5.4. 0520.3.5.5 shall apply to all columns.

0520.3.5.2 Spacing of transverse reinforcement at flexural yielding regions

At both ends of a column, hoops shall be provided at a spacing of s_o over a length l_o measured from the joint face. The spacing s_o shall not exceed the smallest of 8 times the diameter of the smallest longitudinal bar enclosed, 24 times the diameter of the hoop bar, one-half of the smallest cross-sectional dimension of the column, and 300 mm. The length l_o shall not be less than the greatest of one-sixth of the clear span of the column, maximum cross-sectional dimension of the column, and 450 mm.

0520.3.5.3 Location of first hoop

The first hoop shall be located not more than $s_o/2$ from the joint face.

0520.3.5.4 Spacing of transverse reinforcement outside potential plastic hinge regions

Spacing of transverse reinforcement outside the length l_o shall be in accordance with 0505.5.2 and 0507.4.2(1).

0520.3.5.5 Reinforcement at joints

Reinforcement at joints shall conform to 0507.11.2.

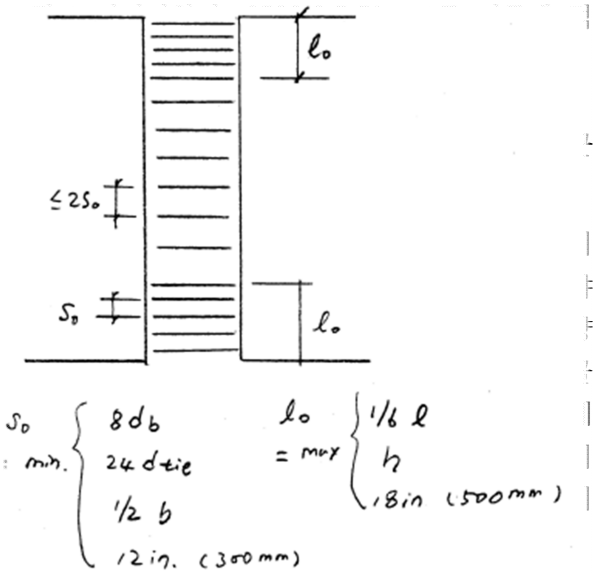
0520.3.6 Two-way slabs without beams

0520.3.6.1 Factored slab moment at support

Factored slab moment at the support including earthquake effects shall be calculated for load combinations specified in Eqs. (0503.3.5) and (0503.3.8). Reinforcement to resist M_{slab} shall be placed within the column strip specified in

0520.3.5.1 적용규정

기둥은 0505.5.2에 따라 나선철근을 배치하거나, 다음 0520.3.5.2, 0520.3.5.3, 0520.3.5.4의 규



0520.3.5.3 첫 번째 후프철근의 위치

첫 번째 후프철근은 접합면으로부터 거리 $s_o/2$ 이내에 있어야 한다.

0520.3.5.4 휨항복 발생구간 이외의 횡보강철근 간격

길이 l_o 이외의 구간에서 횡보강철근의 간격은 0505.5.2와 0507.4.2(1)를 따라야 한다.

0520.3.5.5 접합부 철근

접합부 철근은 0507.11.2에 따라야 한다.

0520.3.6 보가 없는 2방향슬래브

0520.3.6.1 슬래브 받침부에서 계수휨모멘트

슬래브 받침부에서 지진에 의한 계수휨모멘트는 식(0503.3.5)와 식(0503.3.8)에 의한 조합하중에 따라 결정하여야 한다. 슬래브의 휨모멘트 M_{slab}에 저항할 모든 철근은 0510.3.1.2에서 규정하고 있는 주열대 내에 배치하여야 한다.

0510.3.1(2).

Two way slabs without beams
(Flat slab, Flat plate)
are permitted for intermediate
moment frame.
But they are not permitted
for special moment frame.

0520.3.6.2 Reinforcement within effective slab width

Effective slab width for exterior and corner connections shall not extend a distance greater than c_t, which is measured perpendicular to the slab span, beyond the column face.

0520.3.6.3 Reinforcement in column strip at support

At least one-half of the reinforcement in the column strip at the support shall be provided within the effective slab width $(c_2 + 3h)$.

받침부에서 주열대 내의 철근 중 1/2 이상은 기둥을 중심으로 슬래브의 유효폭$(c_2 + 3h)$ 내에 배치하여야 한다.

0520.3.6.4 Continuity of top reinforcement in column strip

At least one-quarter of the top reinforcement at the support in the column strip shall be continuous throughout the span.

0520.3.6.4 주열대 상부철근의 연속

주열대 내 받침부의 상부철근 중 1/4 이상은 전체 경간에 걸쳐서 연속되어야 한다.

0520.3.6.5 Continuous bottom reinforcement in column strip

Continuous bottom reinforcement in the column strip shall be at least one-third of the top reinforcement at the support in the column strip.

0520.3.6.5 주열대내 하부 연속철근

주열대 내 하부 연속철근은 주열대 내 받침부의 상부철근의 1/3 이상이어야 한다.

0520.3.6.6 Continuity of bottom reinforcement at mid-span

At least one-half of all bottom column strip reinforcement and all bottom middle strip reinforcement at the mid-span shall be continuous, and shall develop the design specified yield strength at the face of the support as defined in 0510.4.2(5).

0520.3.6.6 경간 중앙부 하부철근의 연속

경간 중앙부의 모든 중간대 하부철근과 주열대 하부철근의 1/2 이상이 연속되어야 하고, 0510.4.2(5)에서 규정된 받침면에서 설계기준항복강도에 도달할 수 있도록 하여야 한다.

0520.3.6.7 Development of reinforcement at support of slab discontinuous edge

At discontinuous edges of the slab, all top and

0520.3.6.7 슬래브 불연속단 받침부의 철근정착

슬래브의 불연속단의 받침부에서의 상부 및 하부

bottom reinforcement at the support shall be developed at the face of the support as defined in 0510.4.2(5).

철근은 0510.4.2(5)에서 정한 바와 같이 받침면에서 충분히 정착되어야 한다.

0520.3.6.8 Factored gravity load limits

At the critical sections of the column specified in 0507.12.1(3), two-way shear induced by factored gravity loads shall not exceed $0.4\phi V_c$, where V_c shall be calculated in accordance with 0507.12.1(2) for non-prestressed members or 0507.12.2(3) for prestressed members. This requirement shall be permitted not to be satisfied if the unbalanced moment caused by earthquake effects is not greater than one-half of the unbalanced moment strength ϕM_n, which is calculated by 0507.12.7.

0520.3.6.8 계수중력하중의 제한

0507.12.1.3에서 규정된 기둥의 위험단면에서 계수중력하중에 의한 2방향 전단력은 $0.4\phi V_c$ 이하가 되어야 한다. V_c는 프리스트레스를 받지 않는 부재의 경우 0507.12.2.2에 따라 산정하여야 하며, 프리스트레스를 받는 부재의 경우는 0507.12.2.3을 적용하여야 한다. 그러나 지진하중으로 인한 불균형휨모멘트가 0507.12.7에서 산정한 불균형휨강도 ϕM_n의 1/2 이하라면 위의 요구사항은 적용하지 않을 수 있다.

0520.4 Flexural members of special moment frames

0520.4 특수모멘트골조의 휨부재

0520.4.1 Scope

0520.4.1 적용범위

0520.4.1.1 General

Provisions of 0520.4 shall apply to special moment frame members, which are subjected to seismic forces and are proportioned primarily to resist flexure.

0520.4.1.1 일반사항

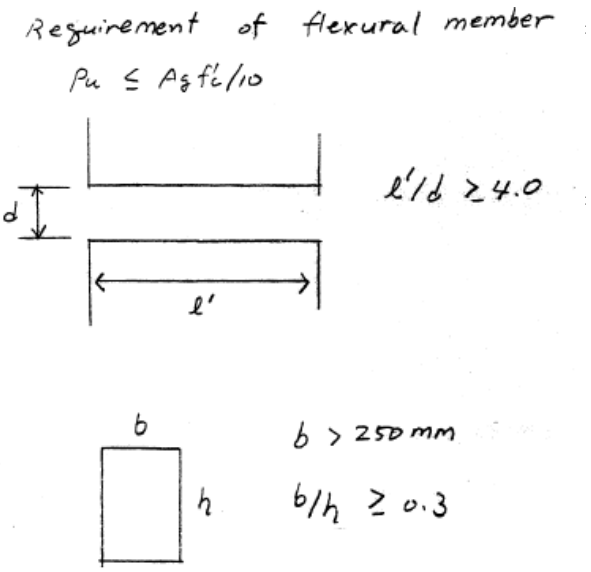
0520.4의 규정은 지진력을 받고, 주로 휨을 받도록 설계된 특수모멘트골조 부재에 적용하여야 한다.

0520.4.1.2 Requirements

These frame members shall also satisfy the following requirements.

(1) Factored axial compressive force shall not exceed $(A_g f_{ck}/10)$.
(2) Clear span shall not be less than four times the effective depth.
(3) Ratio of width to depth shall not be less than 0.3.
(4) Width shall not be less than 250 mm.
(5) Width shall not exceed the sum of the supporting member width measured perpendicular to the axis of the flexural member and 0.75 times the flexural member depth

0520.4.1.2 요구사항



on each side of the supporting member.

0520.4.2 Longitudinal reinforcement

0520.4.2.1 Reinforcement limits

At any section of a flexural member, except as provided in 0506.3.2(3), for both top and bottom reinforcement, the amount of reinforcement shall not be less than that given by Eq. (0506.3.1), but not less than $1.4b_w d/f_y$. The reinforcement ratio ρ shall not exceed 0.025. For both top and bottom reinforcement, at least two continuous bars shall be provided.

$0.025 > \rho > 1.4 b_w d / f_y$

The maximum requirement of ρ ($\varepsilon_t = 0.004$) can not be directly applied to the flexural member under cyclic loads.

Continuity of longitudinal Reinforcement

0520.4.2.2 Moment strength limits

The positive moment strength at a joint face shall not be less than one-half of the negative moment strength provided at the joint face. At any location of the member, both the positive and negative moment strength shall not be less than one-fourth of the maximum moment strength provided at the face of either joint.

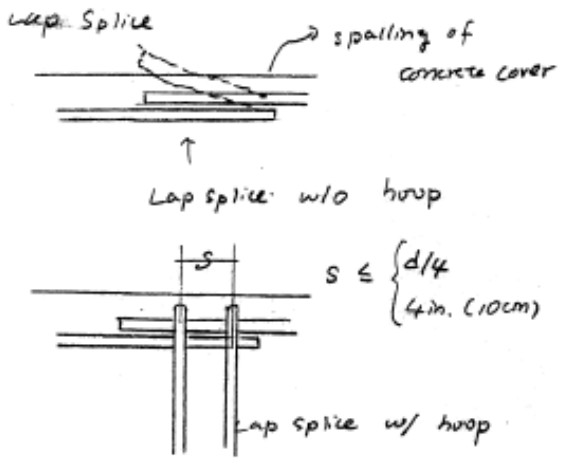
$M_n^+ \geq M_n^- / 2$ at joint

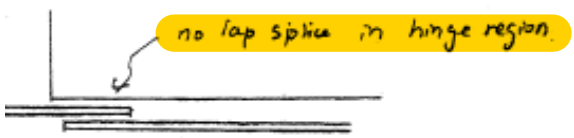
($\rho' \geq \rho / 2$)

$\pm M_n$ at center $\geq \dfrac{M_n^{max} \text{ at joint}}{4}$

0520.4.2.3 Lap splices of flexural reinforcement

Lap splices of flexural reinforcement shall be permitted only if hoop or spiral reinforcement is provided over the lap length. Spacing of the transverse reinforcement enclosing the lap-spliced bars shall not exceed the lesser of $d/4$ and 100 mm. Lap splices shall not be used within the joints, within a distance of twice the member depth from the joint face, and where flexural yielding is expected by analysis as a result of inelastic lateral displacements of the frame.





0520.4.2.4 Mechanical and welded splices

Mechanical splices and welded splices shall conform to 0520.1.5.4 and 0520.1.5.5, respectively.

0520.4.3. Transverse reinforcement

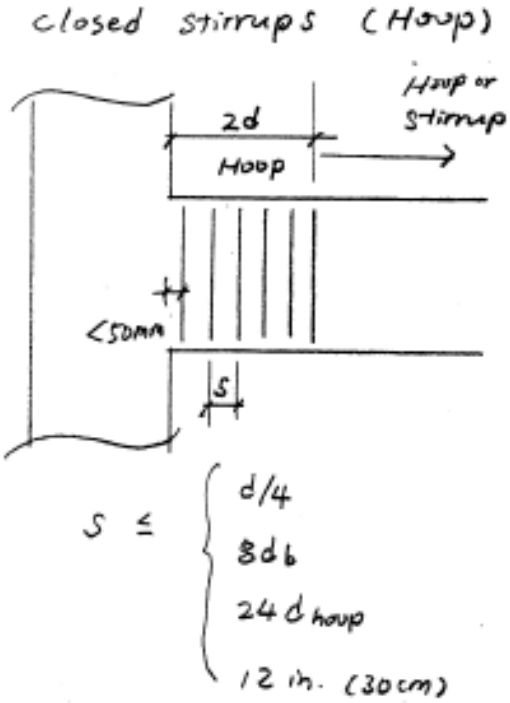
0520.4.3.1 Scope

0520.4.3.1 적용범위

Hoops shall be provided in the following regions of frame members.

(1) Over a length equal to twice the member depth measured from the face of the supporting member toward the mid-span, at both ends of the flexural member.

(2) Over lengths equal to twice the member depth on both sides of a section where flexural yielding is likely to occur as a result of inelastic lateral displacements of the frame.



0520.4.3.2 Spacing of hoops

The first hoop shall be located not more than 50 mm from the face of the supporting member. Spacing of the hoops shall not exceed the smallest of $d/4$, 8 times the diameter of the smallest longitudinal bars, 24 times the diameter of the hoop bars, and 300 mm.

0520.4.3.3 Lateral support of hoops

Where hoops are required, longitudinal bars enclosed by hoops shall have lateral support in accordance with 0505.5.2.3(3).

0520.4.3.3 후프철근의 횡방향지지

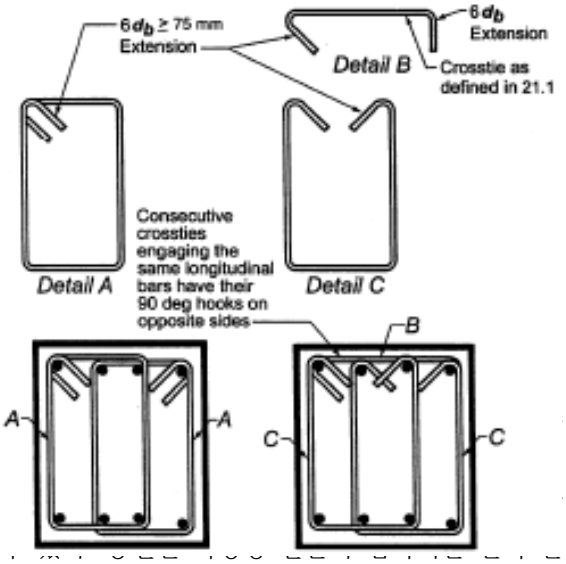
후프철근이 필요한 곳에서 후프철근으로 감싸인 축방향 철근은 0505.5.2.3(3)에 따라 횡방향으로 지지되어야 한다.

0520.4.3.4 Required length for stirrups with seismic hooks

Where hoops are not required, stirrups with seismic hooks at both ends shall be spaced at a distance not exceeding $d/2$ throughout the length of the member.

0520.4.3.4 내진갈고리를 갖춘 스터럽 배치 구간

후프철근이 필요하지 않은 곳에서는 부재의 전 길이에 걸쳐서 $d/2$ 이내의 간격으로 양단 내진



0520.4.3.5 Required length for hoops

Stirrups or ties required to resist shear shall be hoops over the lengths of members as given in 0520.4.3, 0520.5.4, and 0520.6.2.

0520.4.3.6 Hoops in flexural members

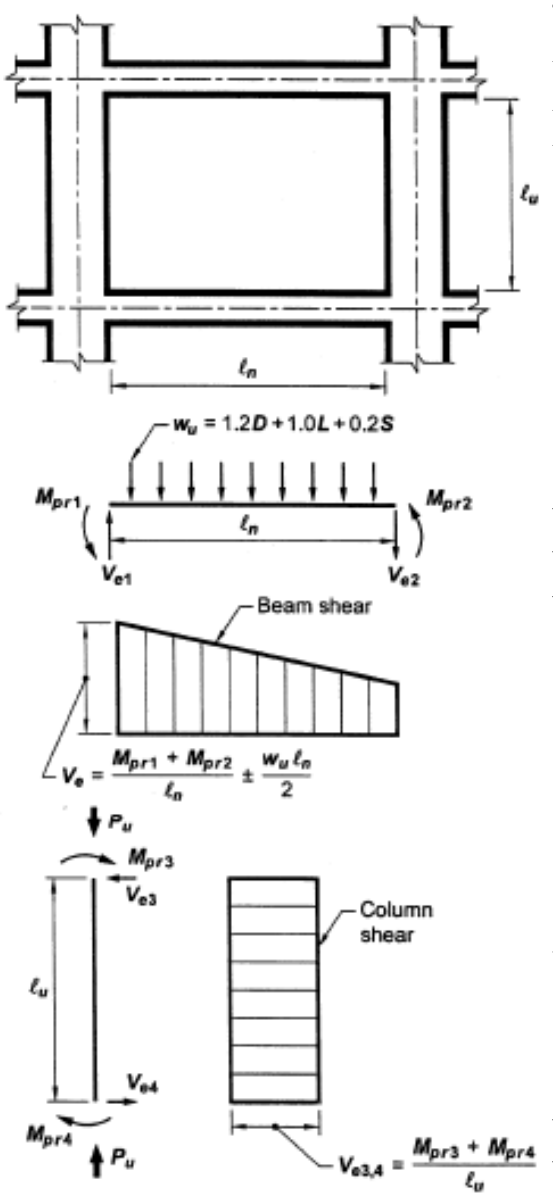
Hoops in flexural members shall be permitted to be made up of two pieces of reinforcement, including a stirrup having seismic hooks at both ends and closed by a cross-tie. Consecutive

cross-ties engaging the same longitudinal bar shall have their 90-degree hooks at the opposite sides of the flexural member. If the longitudinal reinforcing bars secured by the cross-ties are confined by a slab on only one side of the flexural member, the 90-degree hooks of the cross-ties shall be placed on that side.

0520.4.4 Requirements for shear strength

0520.4.4.1 Design shear forces

The design shear force V_e shall be determined by the force equilibrium on the portions of the member between joints faces, assuming that moments of opposite sign corresponding to probable flexural moment strength M_{pr} act at the joint faces and that the member is loaded with the factored tributary gravity load along its span.

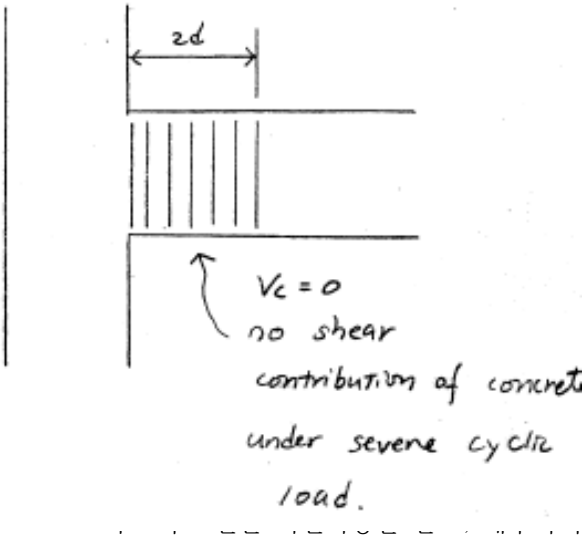


0520.4.4.2 Exemption of concrete contribution to shear

Transverse reinforcement over the lengths defined in 0520.4.3.1 shall be designed to resist shear assuming $V_c = 0$ when both the following conditions occur.

(1) The earthquake-induced shear force calculated from 0520.4.4.1 represents at least one-half of the maximum required shear strength within those lengths.

(2) The factored axial compressive force including earthquake effects is less than $A_g f_{ck}/20$.



0520.5 Special moment frame members subjected to flexure and axial force

0520.5.1 Scope

0520.5.1.1 Applications

Requirements of 0520.5 shall apply to members of special moment frames that resist seismic

forces and are subjected to the factored axial compressive force exceeding $(A_g f_{ck}/10)$.

0520.5.1.2 Dimensional limits

These frame members shall satisfy the followings.

(1) The shortest cross-sectional dimension, measured on a straight line passing through the geometric centroid, shall not be less than 300 mm.

(2) The ratio of the shortest cross-sectional dimension to the perpendicular dimension shall not be less than 0.4.

0520.5.2 Minimum flexural strength of columns

0520.5.2.1 Requirements for flexural strength of columns

The flexural strength of columns exceeding a factored axial compressive force of $(A_g f_{ck}/10)$ shall satisfy 0520.5.2.2 or 0520.5.2.3. If 0520.5.2.2 is not satisfied, the lateral strength and stiffness of the columns framing into that joint shall be ignored when calculating strength and stiffness of the structure. However these columns shall conform to 0520.2.

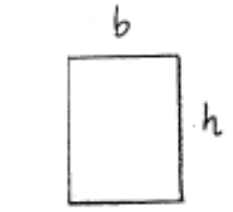
0520.5.2.2 Flexural strength of columns

The flexural strengths of columns shall satisfy Eq. (0520.5.1)

$$\Sigma M_c \geq (6/5)\Sigma M_g \quad (0520.5.1)$$

where, ΣM_c is the sum of nominal flexural strengths of the columns framing into the joint, evaluated at the faces of the joint. Column flexural strength shall be calculated for the factored axial force, consistent with the direction of the lateral forces considered, resulting in the minimum flexural strength. ΣM_g is the sum of nominal flexural strengths of the beams framing into the joint, evaluated at the faces of the joint. In T-beam construction, where the slab acts monolithically with the beam and resists

[illegible] 모멘트골조 부재



시켜야 한다.

댄 최소 단면치수

다.

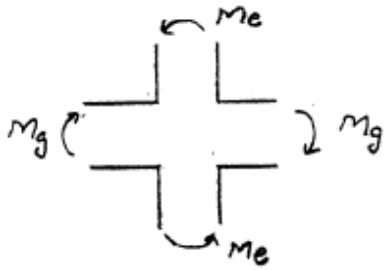
$b \geq 12in.\ (30cm)$

$b/h \geq 0.4$

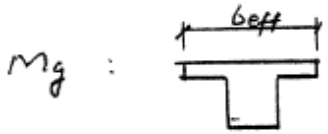
치수에 대한 길이

$P_u > A_g f_{ck}/10$

Strong column ; weak girder



$\Sigma Me \geq \frac{6}{5}\Sigma Mg$



한다.

(0520.5.1)

여기서, ΣM_c는 접합부의 접합면에서 그 접합부에 연결된 기둥의 설계용 휨강도의 합이다. 기둥의 휨강도는 고려되는 횡력 방향에 일치되게 계수축력을 감안하여 계산하여야 하며, 결과적으로 최소 휨강도이어야 한다. ΣM_g는 접합부의 접합면에서 그 접합부에 연결된 보의 설계휨강도의 총합이다. 슬래브와 일체화되어 휨에 저항하는 T형보의 휨강도는 0503.4.8에 규정된 슬래브 유효폭 내에 있는 슬래브 철근을 고려하여 산정하여야 한다.

flexure together, slab reinforcement within the effective slab width defined in 0503.4.10 shall be considered in the evaluation of the flexural strengths.

0520.5.2.3 Direction of column moments

Flexural strengths shall be summed such that the column moments oppose the beam moments. Eq. (0520.5.1) shall be satisfied for beam moments acting in both directions in the vertical plane of the frame considered.

0520.5.2.4 Transverse reinforcement at joints

If 0520.5.2.2 is not satisfied at a joint, columns subjected to reactions from that joint shall be reinforced with transverse reinforcement as specified in 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 over the full height.

0520.5.3 Longitudinal reinforcement

0520.5.3.1 Reinforcement ratio limits

Longitudinal reinforcement ratio ρ_g shall not be less than 0.01 and shall not exceed 0.06.

0520.5.3.2 Splices of reinforcement

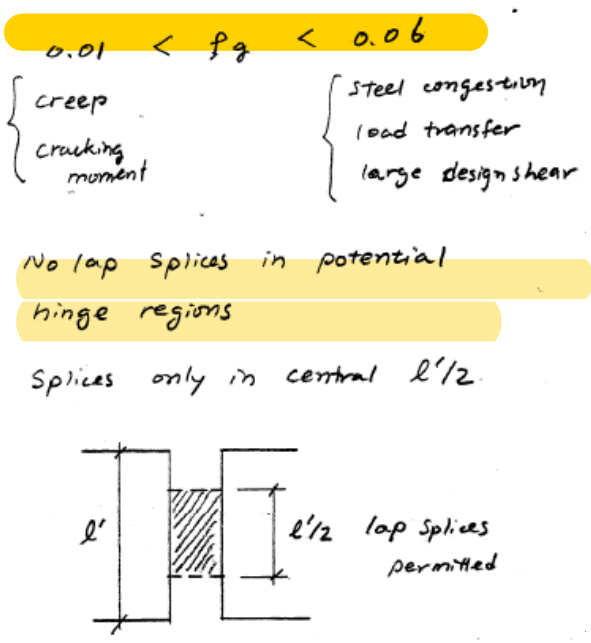
Mechanical splices shall conform to 0520.1.5.4 and welded splices shall conform to 0520.1.5.5. Lap splices shall be permitted only within the center half of the member length, shall be designed as tension lap splices, and shall be enclosed with transverse reinforcement conforming to 0520.5.4.2 and 0520.5.4.3.

0520.5.4 Transverse reinforcement

0520.5.4.1 Details of transverse reinforcement

Transverse reinforcement shall conform to the following requirements of (1) to (5), unless a larger amount is required by 0520.5.3.2 or 0520.5.5.

(1) The volumetric ratio of spiral or circular



에 따라 횡방향 철근으로 보강하여야 한다.

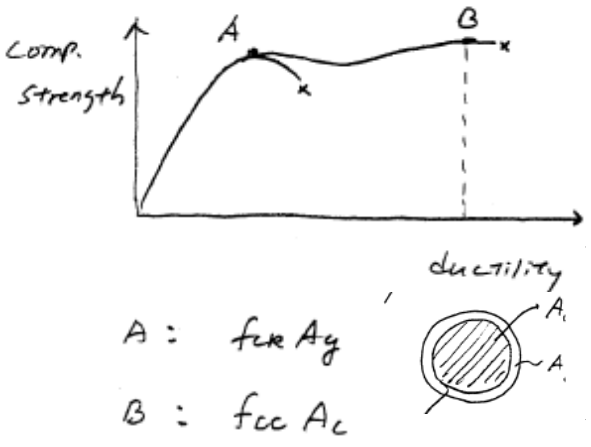
0520.5.3 축방향 철근

0520.5.3.1 철근비 제한

철근비 ρ_g는 0.01 이상, 0.06 이하이어야 한다.

0520.5.3.2 철근이음

기계적이음은 0520.1.5.4에 따라야 하며, 용접이음은 0520.1.5.5에 따라야 한다. 겹침이음은 부재의 중앙부에서 부재길이 1/2구역 내에서만 할 수 있고 인장이음으로 설계하여야 하며, 또한 0520.5.4.2와 0520.5.4.3의 규정을 따르는 횡방



hoop reinforcement ρ_s shall not be less than that required by Eq. (0520.5.2), and shall not be less than that required by Eq. (0506.4.1).

$$\rho_s = 0.12 f_{ck}/f_{yh} \qquad (0520.5.2)$$

(2) The total cross-sectional area of rectangular hoop reinforcement shall not be less than that required by Eqs. (0520.5.3) and (0520.5.4).

$$A_{sh} = 0.3(sh_c f_{ck}/f_{yh})[(A_g/A_{ch}) - 1] \qquad (0520.5.3)$$

$$A_{sh} = 0.09 sh_c f_{ck}/f_{yh} \qquad (0520.5.4)$$

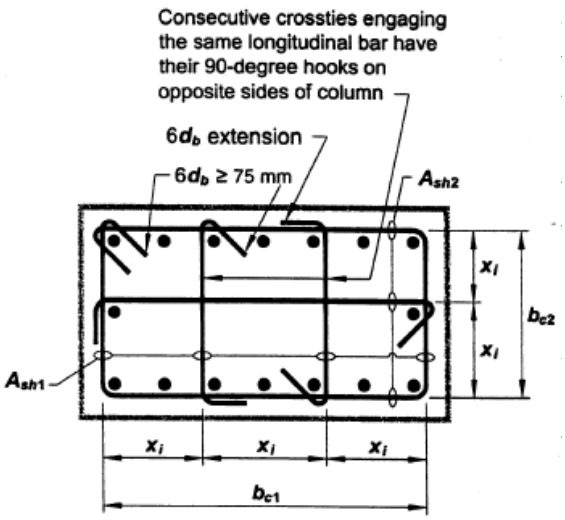
(3) Transverse reinforcement shall comprise either single or overlapping hoops. Cross-ties of the same bar size and spacing as the hoops shall be permitted. The end of cross-ties shall engage peripheral longitudinal reinforcement, and consecutive cross-ties shall be alternated end for end along the longitudinal reinforcement.

(4) If the design strength of the member core exceeds the strength calculated from design load combinations including earthquake effects, it shall be permitted not to conform to Eqs. (0520.5.3) and (0506.4.1).

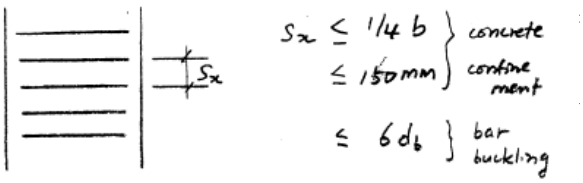
(5) Additional transverse reinforcement shall be provided if the concrete cover outside the confining transverse reinforcement is greater than 100 mm. For the additional transverse reinforcement, concrete cover shall not exceed 100 mm, and spacing shall not exceed 300 mm.

식(0520.5.2)로 결정된 값 이상으로 하여야 하며, 또한 식(0506.4.1)으로 계산된 값 이상으로 하여야 한다.

(2) 사각형 후프철근의 전체 단면적은 식(0520.5.3)과 식(0520.5.4)로 계산되는 값 이상으로 하여야 한다.



The dimension x_i from centerline to centerline of tie legs is not to exceed 350 mm. The term h_x used in equation 21-2 is taken as the largest value of x_i.



0520.5.4.2 Spacing of transverse reinforcement

Spacing of transverse reinforcement shall not exceed the smallest of one-quarter of the minimum member dimension, 6 times the diameter of the smallest longitudinal bar, and s_x as defined by Eq. (0520.5.5).

$$s_x = 100 + [(350 - h_x)/3] \qquad (0520.5.5)$$

0520.5.4.2 횡방향 철근간격

횡방향 철근간격은 부재의 최소 단면치수의 1/4, 축방향 철근 지름의 6배, 또한 식(0520.5.5)에 규정한 s_x 중 가장 작은 값 이하로 한다.

where, s_x shall not exceed 150 mm and need not be taken less than 100 mm.

여기서, s_x 값은 150 mm 이하이어야 하며, 100 mm 이하일 필요는 없다.

0520.5.4.3 Spacing of cross-ties or overlapping hoops

Spacing of cross-ties or overlapping hoops shall not exceed 350 mm on center within the cross-section of a member.

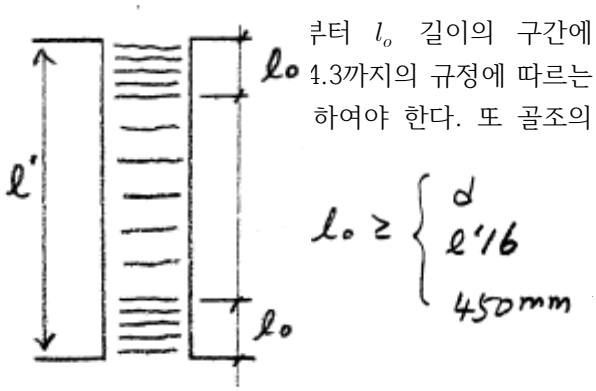
0520.5.4.3 연결철근이나 겹침후프철근 간격 제한

연결철근이나 겹침후프철근은 부재의 단면 내에서 중심간격이 350 mm 이내가 되도록 배치하여야 한다.

0520.5.4.4 Flexural yielding regions

Transverse reinforcement conforming to 0520.5.4.1 through 0520.5.4.3 shall be provided over a length l_o from each joint face. Also, it shall be provided on both sides of any section where flexural yielding is expected to occur as a result of inelastic lateral displacements of the frame. l_o shall not be less than the largest of the depth of the member at the joint face or at the section where flexural yielding is likely to occur, one-sixth of the clear span of the member, and 450 mm.

0520.5.4.4 휨항복 발생구간



큰터 l_o 길이의 구간에
4.3까지의 규정에 따르는
하여야 한다. 또 골조의

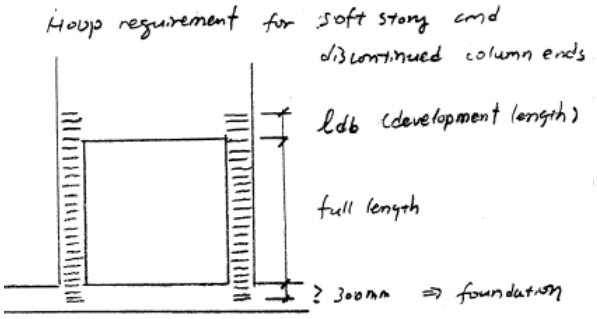
0520.5.4.5 Columns supporting discontinued stiff members

Columns supporting reactions from discontinued stiff members, such as walls, shall satisfy the followings.

(1) Transverse reinforcement as required in 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 shall be provided over the full height at all levels up to the discontinuity, if the factored axial compressive force of the members by earthquake effects exceeds $(A_g f_{ck}/10)$.

(2) Transverse reinforcement shall extend into the discontinued member at least l_d of the largest longitudinal column bar, where l_d is determined in accordance with 0506.4. Where the lower end of the column terminates on a wall, the required transverse reinforcement by 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 shall extend into the wall at least l_d of the largest longitudinal column bar at

0520.5.4.5 불연속 강성부재를 지지하는 기둥



(2) 횡보강철근은 최소한 가장 굵은 축방향 철근의 정착길이만큼 불연속 부재의 내부로 배치되어야 한다. 이때 축방향 철근의 정착길이는 0506.4의 규정에 의해 정해진다. 기둥의 하단이 벽체 위에서 끝나게 되는 경우 0520.5.4.1, 0520.5.4.2, 0520.5.4.3에 의한 횡방향 철근은 기둥이 끝나는 점에서 최대 축방향 철근의 정착구간까지 벽체 속으로 배치되어야 하고, 기둥이 일반 기초나 전면기초

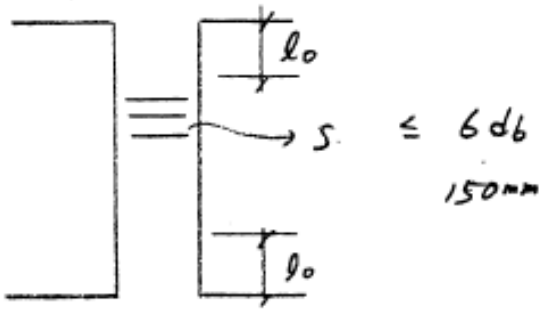
the point of termination. Where the column terminates on a footing or mat, the required transverse reinforcement by 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 shall extend at least 300 mm into the footing or mat.

위에 끝날 경우는 0520.5.4.1, 0520.5.4.2, 0520.5.4.3의 규정에 의해 결정되는 횡방향 철근은 일반 기초나 전면기초 내 최소한 300 mm의 구간까지 배치되어야 한다.

0520.5.4.6 Minimum spacing of transverse reinforcement

Where the required transverse reinforcement by 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 is not provided throughout the full length of the column, the remainder of the column length shall contain spiral or hoop reinforcement with a center-to-center spacing not exceeding the lesser of six times the diameter of the longitudinal column bars and 150 mm.

0520.5.4.6 횡방향철근 최소배근간격



0520.5.5 Requirements for shear strength

0520.5.5.1 Design shear forces

The design shear force V_e shall be determined from considering the maximum forces that can be generated at the faces of the joints at each end of the member. These joint forces shall be determined using the maximum probable moment strengths M_{pr} at each end of the member associated with the range of factored axial loads acting on the member. The design shear force V_e need not exceed that determined from joint strengths based on M_{pr} of the transverse members framing into the joint, but, in any case, V_e shall not be less than the factored shear determined by analysis of the structure.

0520.5.5 전단강도 요구 사항

0520.5.5.1 설계전단력

설계전단력 V_e는 부재 각 단부의 접합부 면에서 발생 가능한 최대 전단력으로 결정되며, 이러한 접합면의 힘은 부재의 계수축력을 고려한 예상 최대 휨강도 M_{pr}를 사용하여 결정한다. 접합부에 연결된 횡부재의 예상최대휨강도 M_{pr}에 근거한 접합부 강도에 의해 계산된 전단력보다 클 필요가 없으나 어떤 경우에도 V_e는 구조물 해석에 의하여 구한 계수전단력 이상이어야 한다.

0520.5.5.2 Exemption of concrete contribution to shear

Transverse reinforcement over the length l_o defined in 0520.5.4.4 shall be designed to resist shear assuming $V_c = 0$ when both the following (1) and (2) are satisfied.

(1) The earthquake-induced shear force, calculated in accordance with 0520.5.5.1, is

0520.5.5.2 콘크리트 전단기여도 제외 규정

0520.5.4.4에서 정의된 l_o에 대한 횡방향철근은 다음 (1)과 (2)를 모두 만족하는 경우 $V_c = 0$으로 보고 전단력에 저항할 수 있도록 설계하여야 한다.

(1) 0520.5.5.1에 의해 계산된 지진하중에 의한 전단력이 그 길이에서 최대 소요전단강도의

more than 1/2 of the maximum required shear strength within the length.

(2) The factored axial compressive force including earthquake effect is less than $A_g f_{ck}/20$.

1/2 이상인 경우

(2) 지진하중에 의한 계수축력이 $A_g f_{ck}/20$보다 작은 경우

0520.6 Joints of special moment frames

0520.6 특수모멘트골조의 접합부

0520.6.1 General

0520.6.1 일반사항

0520.6.1.1 Design stress of flexural tensile reinforcement

Forces in longitudinal beam reinforcement at the joint face shall be determined assuming that the stress in the flexural tensile reinforcement is $1.25 f_y$.

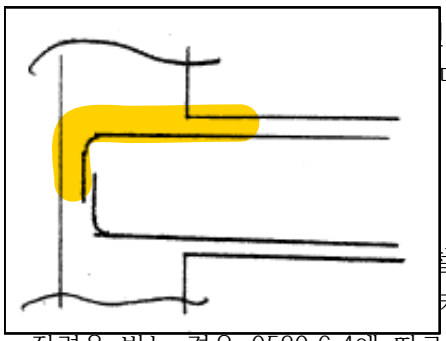
0520.6.1.1 휨인장철근 설계응력

접합면에서 보의 종방향 철근의 작용력은 휨인장철근의 응력을 $1.25 f_y$라고 가정하여 결정하여야 한다.

0520.6.1.2 Strength of joints

Strength of joints shall be determined in accordance with the strength reduction factors specified in 0503.3.3.

0520.6.1.2 접합부의 강도



해당 강도감
다.

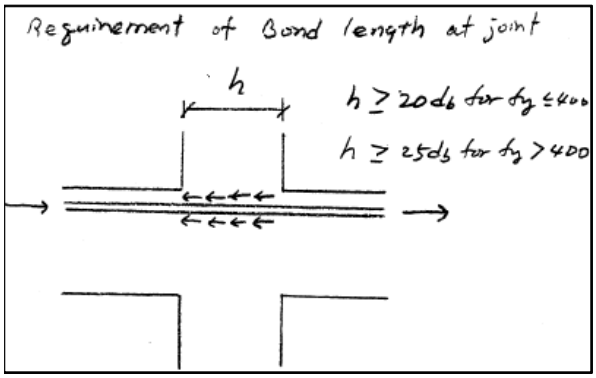
0520.6.1.3 Longitudinal reinforcement of beams

Beam longitudinal reinforcement terminated in a column shall extend to the opposite face of the confined column core, and shall be anchored in accordance with 0520.6.4 in tension and 0508 in compression.

철근은 횡보강
켜야 하며, 인
장력을 받는 경우 0520.6.4에 따르고, 압축력을 받는 경우 0508을 따라야 한다.

0520.6.1.4 Requirements for column dimension

Where longitudinal beam reinforcement extends through a beam-column joint, the column dimension h parallel to the beam reinforcement shall satisfy Eq. (0520.6.1) for normal-weight concrete.



$$f_y \le 400\text{MPa}, \quad \frac{h}{d_b} \ge 20 \qquad (0520.6.1a)$$

$$f_y > 400\text{MPa}, \quad \frac{h}{d_b} \ge 25 \qquad (0520.6.1b)$$

For lightweight concrete, Eq. (0520.6.2) shall be satisfied.

경량콘크리트인 경우는 식 (0520.6.2)를 만족하여야 한다.

$$\frac{h}{d_b} \geq 26\frac{f_y}{400} \geq 26$$ (0520.6.2)

0520.6.2 Transverse reinforcement

0520.6.2.1 Scope

Transverse hoop reinforcement conforming to 0520.5.4 shall be provided within the joint, if the joint is not confined by structural members as specified in 0520.6.2.2.

0520.6.2.2 For joints confined by beams on all four faces

Where beams frame into all four sides of the joint and where each beam width exceeds three-fourths the column width, the amount of reinforcement specified in 0520.5.4.1 shall be permitted to be reduced by one-half within the overall depth of the shallowest framing member. In these regions, the spacing required by 0520.5.4.2 shall be permitted to be increased to 150 mm.

0520.6.2.3 For joints not confined by beams on all four faces

Transverse reinforcement as required by 0520.5.4 shall be provided in the joint, if longitudinal beam reinforcement outside the column core is not confined by a beam framing into the joint.

0520.6.3 Shear strength

0520.6.3.1 Nominal shear strength of joints

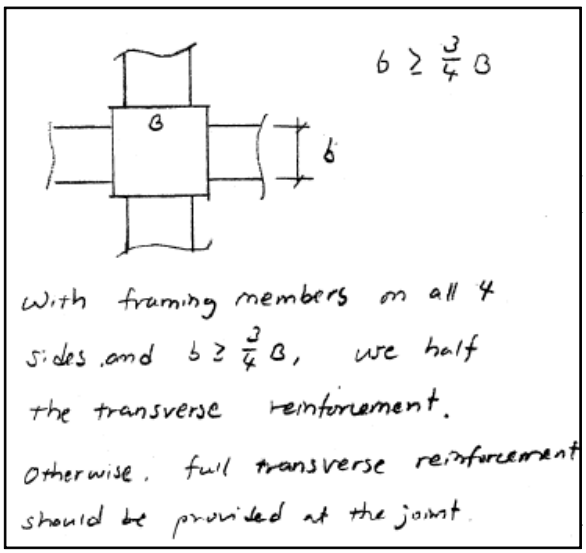
The nominal shear strength of the joint shall not exceed the following values for normal-weight concrete.

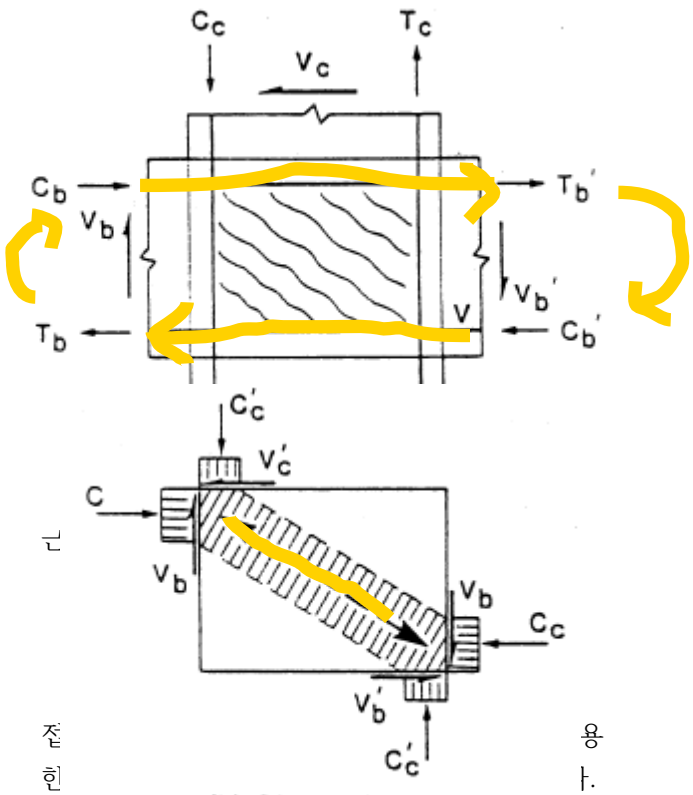
(1) For joints confined by beams on all four faces, $1.7\sqrt{f_{ck}}A_j$

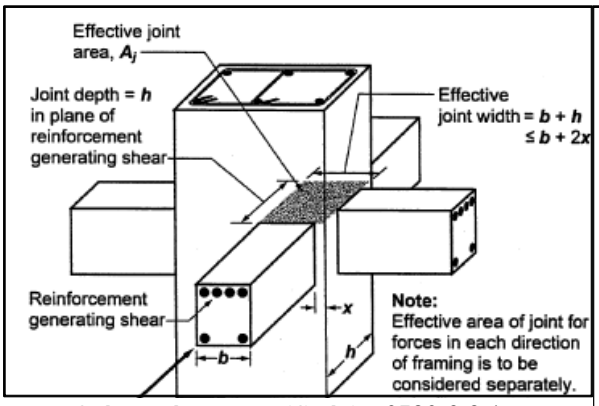
(2) For joints confined by beams on three faces or on two opposite faces, $1.2\sqrt{f_{ck}}A_j$

(3) For other cases, $1.0\sqrt{f_{ck}}A_j$

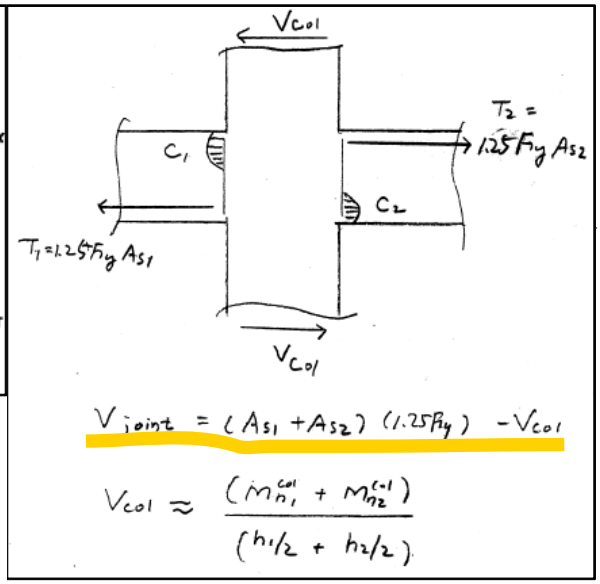
A member framing into a joint face is considered to provide confinement to the face







ters of the values specified in 0520.6.3.1.



0520.6.4 Development length of bars in tension

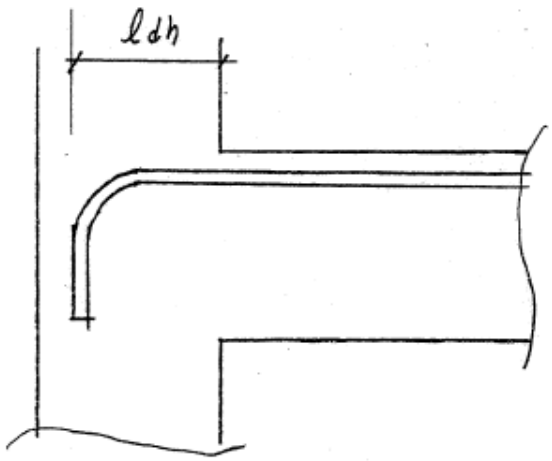
0520.6.4.1 Normal-weight concrete

For normal-weight concrete, the development length l_{dh} for bar sizes D6 through D35 with a standard 90-degree hook shall not be less than the largest of $8d_b$, 150 mm, and the length required by Eq. (0520.6.3).

보통중량콘크리트에서 90° 표준갈고리가 있는 철근의 정착길이 l_{dh} 는 D6에서 D35까지의 철근의 경우 $8d_b$ 이상, 150mm 이상 또한 식(0520.6.3)에서 규정된 길이 이상이어야 한다.

$$l_{dh} = f_y d_b / \left(5.4\sqrt{f_{ck}}\right) \qquad (0520.6.3)$$

For lightweight concrete, l_{dh} for a bar with a standard 90-degree hook shall not be less than the largest of $10d_b$, 190 mm, and 1.25 times the length required by Eq. (0520.6.3). The 90-degree hook shall extend to a column or confined concrete of a boundary element.



For $f'_c = 30$ MPa and $f_y = 400$ MPa

$$l_{dh} = \frac{400\, d_b}{5.4\sqrt{30}}$$

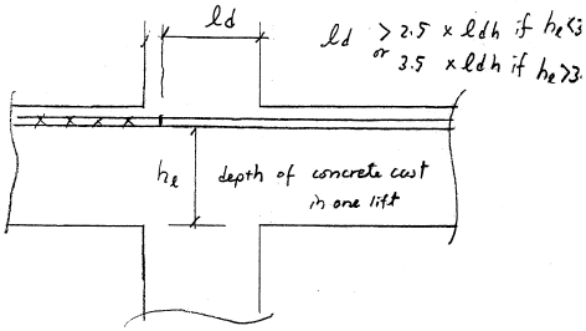
0520.6.4.2 Development length of straight bars

For bar sizes D6 through D35, the development length l_d for a straight bar shall not be less than 2.5 times the length specified in 0520.6.4.1 if the depth of the concrete cast in one lift beneath the bar does not exceed 300 mm, and shall not be less than 3.5 times the length specified in 0520.6.4.1 if the depth of the concrete cast in one lift beneath the bar exceeds 300 mm.

0520.6.4.3 Straight bars terminated at joint

0520.6.4.3 접합부 내의 직선철근

Straight bars terminated at a joint shall pass through the confined core of a column or boundary element. Any portion of the development length not within the confined core shall be increased by a factor of 1.6.



0520.6.4.4 Development length of epoxy-coated reinforcement

The development lengths specified in 0520.6.4.1 to 0520.6.4.3 shall be multiplied by applicable factors in 0508.2.2 if epoxy-coated reinforcement is used.

길이는 0508.2.2
다.

0520.7 Special structural walls and coupling beams

ㅌ 구조벽체와

0520.7.1 Scope

Requirements of this section shall apply to special structural walls and coupling beams forming part of the seismic-force-resisting system.

0520.7.1 적용범위

이 절에 규정된 요구 사항은 지진력 저항 시스템의 한 부분으로 역할을 하는 특수철근콘크리트 구조벽체와 연결보에 적용하여야 한다.

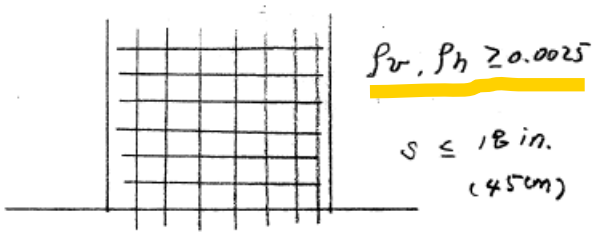
0520.7.2 Reinforcement

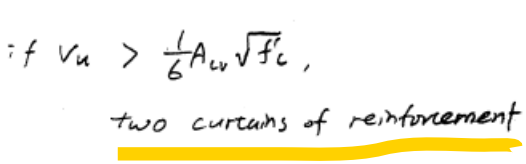
0520.7.2.1 Reinforcement ratio of structural walls

The distributed web reinforcement ratios, ρ_v and ρ_h, for structural walls shall not be less than 0.0025. However, if the design shear force does not exceed $(\sqrt{f_{ck}}/12)A_{cv}$, the minimum reinforcement of structural walls shall be permitted to be reduced to the values required in 0511.3. Reinforcement spacing each way in structural walls shall not exceed 450 mm. Reinforcement contributing to shear strength shall be continuous and shall be distributed across the shear plane.

0520.7.2 철근

0520.7.2.1 구조벽체의 철근비





0520.7.2.2 Two curtains of reinforcement

If the in-plane factored shear force in a wall is greater than $(\sqrt{f_{ck}}/6)A_{cv}$, at least two curtains of reinforcement shall be used.

0520.7.2.2 2단 배근 배치규정

벽체에 작용하는 면내 계수전단력이 $(\sqrt{f_{ck}}/6)A_{cv}$를 초과하면 철근은 적어도 복배근으로 배치하여야 한다.

0520.7.2.3 Splices and development of continuous reinforcement

All continuous reinforcement in structural walls shall be spliced and developed in accordance with 0508.5.1 for reinforcement in tension, except as provided in the followings.

(1) The effective depth d in 0508.5.1(2) shall be permitted to be taken as $0.8l_w$.

(2) The requirements of 0508.5.2, 0508.5.3, and 0508.5.4 need not be applied.

(3) At locations where yielding of longitudinal reinforcement is likely to occur as a result of displacements by lateral loads, development lengths of longitudinal reinforcement shall be 1.25 times the values calculated for the specified yield strength in tension.

(4) Mechanical splices and welded splices of reinforcement shall conform to 0520.1.5.4 and 0520.1.5.5, respectively.

0520.7.3 Design forces

The factored shear force V_u shall be determined from the lateral load analysis in accordance with the factored loads and load combinations.

0520.7.4 Shear strength

0520.7.4.1 Nominal shear strength of structural walls

The nominal shear strength of structural walls shall not exceed the value calculated by Eq. (0520.7.1).

$$V_n = A_{cv}(\alpha_c \sqrt{f_{ck}} + \rho_n f_y) \quad (0520.7.1)$$

where, the coefficient α_c is 1/4 for $h_w/l_w \le 1.5$, 1/6 for $h_w/l_w \ge 2.0$, and varies linearly between 1/4 and 1/6 for $1.5 \le h_w/l_w \le 2.0$.

0520.7.2.3 연속철근의 이음과 정착

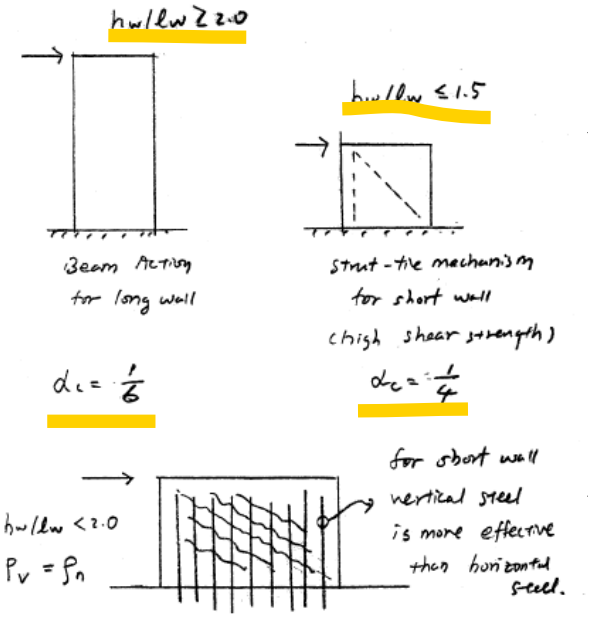
구조벽체의 모든 연속철근의 이음과 정착은 다음 사항을 제외하고, 0508.5.1의 인장을 받는 철근에 대한 규정을 따라야 한다.

(1) 0508.5.1(2)에서 유효깊이 d는 $0.8l_w$를 사용할 수 있다.

(2) 0508.5.2, 0508.5.3, 0508.5.4의 규정은 적용될 필요가 없다.

(3) 횡하중에 의해 발생한 변위에 대하여 철근의 항복이 예상되는 곳에서는 철근의 설계기준 항복강도를 1.25배 하여 정착길이를 산정하여야 한다.

(4) 기계적이음과 용접이음은 0520.1.5.4과 0520.1.5.5의 규정을 따라야 한다.



(0520.7.1)

여기서, 계수 α_c의 값은 $h_w/l_w \le 1.5$일 때 1/4, $h_w/l_w \ge 2.0$일 때 1/6이고, $1.5 \le h_w/l_w \le 2.0$일 때는 1/4와 1/6을 선형보간하여 결정하여야 한다.

0520.7.4.2 h_w/l_w for segments of wall

In 0520.7.4.1, the value of h_w/l_w used to calculate V_n for segments of a wall shall be the greater of the ratios for the entire wall and the segment of the wall considered.

0520.7.4.3 Shear reinforcement in two orthogonal directions

Walls shall have distributed shear reinforcement in two orthogonal directions in the plane of the wall. The reinforcement ratio ρ_v shall not be less than the reinforcement ratio ρ_n, if h_w/l_w does not exceed 2.0.

0520.7.4.4 Nominal shear strength of vertical wall segments

For all vertical wall segments sharing a common lateral force, the nominal shear strength shall not be taken greater than $2(\sqrt{f_{ck}}/3)A_{cv}$, where A_{cv} is the gross sectional area in the direction of shear force. For an individual vertical wall segment, the nominal shear strength shall not be taken greater than $5(\sqrt{f_{ck}}/6)A_{cp}$, where A_{cp} is the gross sectional area of the individual vertical wall segment considered.

0520.7.4.5 Nominal shear strength of horizontal wall segments and coupling beams

For horizontal wall segments and coupling beams, the nominal shear strength shall not be taken greater than $5(\sqrt{f_{ck}}/6)A_{cp}$, where A_{cp} is the gross sectional area of a horizontal wall segment or coupling beam.

0520.7.5 Design for flexure and axial force

0520.7.5.1 General

Structural walls and portions of such walls subjected to combined flexure and axial force shall be designed in accordance with 0506.2.1 and 0506.2.2. However, 0506.2.1(2) for the non-

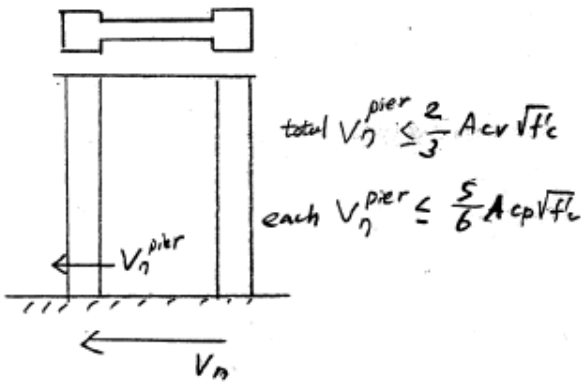
0520.7.4.2 부분벽 또는 부분격막의 h_w/l_w

0520.7.4.1에서 부분벽 또는 부분격막의 V_n을 결정하기 위해 사용되는 h_w/l_w의 값으로 전체 벽체의 값과 고려하는 부분벽의 값 중 더 큰 값을 사용하여야 한다.

0520.7.4.3 전단철근의 2방향 배근

벽체는 면내전단저항력을 갖기 위하여 전단철근을 2방향으로 배치하여야 한다. h_w/l_w비가 2.0을 초과하지 않으면, 철근비 ρ_v는 ρ_n 이상이어야 한다.

0520.7.4.4 횡방향력을 같이 부담하는 벽기둥의 공칭전단강도



0520.7.4.5 수평부분벽과 연결보의 공칭전단강도

수평부분벽과 연결보의 공칭전단강도는 $5(\sqrt{f_{ck}}/6)A_{cp}$를 초과할 수 없다. 여기서, A_{cp}는 수평부분벽 또는 연결보의 단면적을 나타낸다.

0520.7.5 휨모멘트와 축력에 대한 설계

0520.7.5.1 일반사항

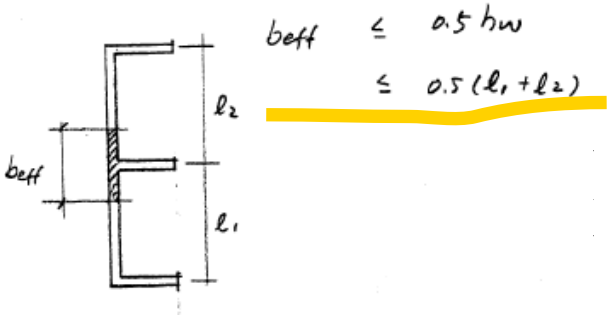
축력과 휨모멘트의 지배를 받는 구조벽체와 그의 부분벽은 0506.2.1과 0506.2.2에 따라 설계하여야 한다. 다만, 0506.2.1.2의 비선형변형률 요구사항과 0506.2.2(5)는 적용하지 않는다. 유효플

linear strain requirements and 0506.2.2(5) shall not be applied. Concrete and longitudinal reinforcement within effective flange widths, boundary elements, and the wall web shall be considered effective, and the effects of openings shall also be considered.

랜지폭 내의 종방향 철근과 콘크리트, 경계요소, 그리고 벽체복부는 유효한 것으로 간주하고, 개구부의 효과도 고려하여야 한다.

0520.7.5.2 Effective flange width of flanged sections

Unless a more detailed analysis is conducted, effective flange widths of flanged sections shall be the lesser of 1/2 of the distance to an adjacent wall web and 1/4 of the total wall height.



0520.7.6 Boundary elements of special structural walls

0520.7.6 특수철근콘크리트 구조벽체의 경계

0520.7.6.1 General

The need for special boundary elements at the edges of structural walls shall be evaluated in accordance with 0520.7.6.2 or 0520.7.6.3. The requirements of 0520.7.6.4 and 0520.7.6.5 shall also be satisfied.

0520.7.6.2 Design of special boundary elements

This section shall apply to walls or wall piers that are effectively continuous from the base of the structure to the top of the walls and are designed to have a single critical section for flexure and axial force. Walls not satisfying the following requirements shall be designed in accordance with 0520.7.6.3.

(1) Compression zones shall be reinforced with special boundary elements where the following is satisfied.

$$c \geq \frac{l_w}{600(\delta_u/h_w)} \qquad (0520.7.2)$$

where δ_u/h_w shall not be taken less than 0.007.

여기서, δ_u/h_w는 0.007 이상이어야 한다.

(2) Where special boundary elements are re-

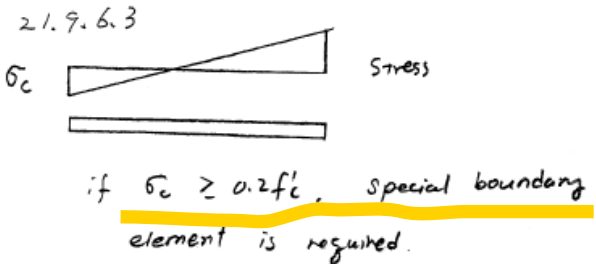
(2) (1)에 의해 특수경계요소가 요구되는 경우,

quired by (1), reinforcement of the special boundary elements shall extend vertically from the critical section at least the greater of l_w and $M_u/4V_u$.

특수경계요소 보강은 위험단면부터 연직방향으로 l_w 와 $M_u/4V_u$ 중 큰 값 이상의 거리까지 연장하여야 한다.

0520.7.6.3 Alternative design of special boundary elements

Structural walls not designed in accordance with 0520.7.6.2 shall have special boundary elements at boundaries and edges around openings of structural walls where the maximum extreme fiber compressive stress, corresponding to load combinations including earthquake effects, exceeds $0.2f_{ck}$. The special boundary element shall be permitted to be discontinued where the calculated compressive stress is less than $0.15f_{ck}$. Stresses shall be calculated for the factored loads using a linearly elastic model and gross sectional properties. For walls with flanges, an effective flange width shall be the lesser of 1/2 of the distance to an adjacent wall web and 1/4 of the total wall height.



수 있다. 이 경우 응력은 선형탄성 모델 및 비균열 단면에 대해 계수하중을 적용하여 계산할 수 있다. 이때 플랜지가 있는 벽체의 경우 유효플랜지폭은 복부 면부터 인접 벽체의 복부까지 거리의 1/2 또는 벽체높이의 1/4 중 작은 값을 취하여야 한다.

0520.7.6.4 Details of special boundary elements

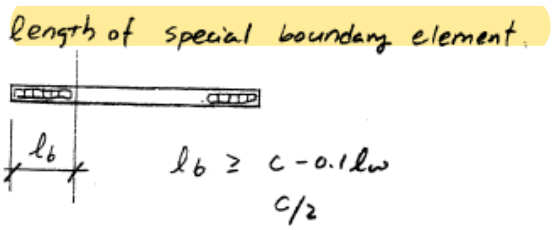
Where special boundary elements are required by 0520.7.6.2 or 0520.7.6.3, (1) through (6) shall be satisfied.

(1) The boundary element shall extend horizontally from the extreme compression fiber a distance not less than the larger of $c-0.1l_w$ and $c/2$.

(2) For walls of flanged sections, the boundary element shall include the effective flange width in compression and extend at least 300 mm into the web.

(3) Transverse reinforcement of the boundary element shall satisfy 0520.5.4.1 through 0520.5.4.3. Eq. (0520.5.3) need not be satisfied, and spacing of transverse reinforcement shall be 1/3 of the least dimension of the boundary element. Transverse reinforcement conforming to 0520.5.4.1(3) shall be in

0520.7.6.4 특수경계요소의 요구상세



The transeverse reinforcement should conform to the requirement of columns.

(3) 특수경계요소의 횡방향 철근은 0520.5.4.1부터 0520.5.4.3까지의 요구사항을 만족시켜야 한다. 다만, 식(0520.5.3)은 만족시킬 필요가 없고, 횡방향 철근 간격은 부재의 최소 단면치수의 1/3을 사용하여야 한다. 또한, 0520.5.4.1(3)에 따른 횡방향 철근은 벽체 최외단부를 감싸는 폐쇄형 후프 형태로서, 경계

the form of closed hoops enclosing the edges of walls and shall be permitted to consist of U-stirrups and cross-ties extending a length equal to the development length beyond the boundary element into the wall web.

요소 설치구간을 넘어 벽체복부 안으로 철근의 정착길이만큼 연장된 U형 스터럽과 연결철근으로 구성할 수 있다.

(4) Transverse reinforcement shall extend into the support a distance not less than the development length in tension of the largest longitudinal reinforcement in the special boundary element. If the special boundary element connects with a footing or mat, transverse reinforcement shall extend at least 300 mm into the footing or mat.

(4) 경계요소에 있는 가장 큰주철근의 인장 정착길이 만큼 횡방향 철근이 받침부 내부로 배치되어야 한다. 다만, 특수경계요소가 기초판 또는 전면기초와 만날 때는 그 안쪽으로 적어도 300 mm 정착시켜야 한다.

(5) Horizontal reinforcement in the wall web shall be anchored to develop the specified yield strength f_y within the confined core of the boundary element.

(5) 벽체 복부의 수평철근은 항복강도 f_y까지 도달할 수 있도록 경계요소의 코어 내부에 정착시켜야 한다.

(6) For longitudinal reinforcement of the boundary element, mechanical splices shall conform to 0520.1.5.4, and welded splices shall conform to 0520.1.5.5.

(6) 경계요소의 종방향철근의 기계적이음은 0520.1.5.4에 따라야 하며, 경계요소의 종방향철근의 용접이음은 0520.1.5.5에 따라야 한다.

0520.7.6.5 Walls without special boundary elements

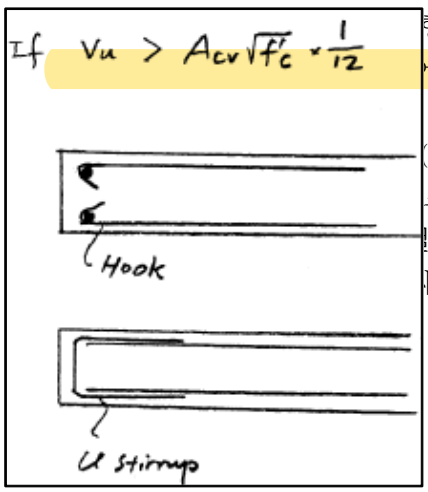
0520.7.6.5 특수경계요소가 필요하지 않은 경우

Where special boundary elements are not required by 0520.7.6.2 and 0520.7.6.3, the followings of (1) and (2) shall be satisfied.

0520.7.6.2와 0520.7.6.3에 의한 특수경계요소가 요구되지 않을 때는 아래 (1)과 (2)를 만족시켜야 한다.

(1) When the longitudinal reinforcement ratio at the wall boundary is larger than $2.8/f_y$, boundary transverse reinforcement shall satisfy 0520.5.4.1(3), 0520.5.4.3, and 0520.7.6.4(1). The longitudinal spacing of boundary transverse reinforcement shall not exceed 200 mm.

(1) 벽체 경계 부분에서 종방향 철근비가 $2.8/f_y$ 보다 크다면, 경계부분의 횡방향철근은 0520.5.4.1(3), 0520.5.4.3과 0520.7.6.4(1)을 만족 [illegible]향 철근의 길 [illegible]어야 한다.



(2) Except where the factored shear force V_u in the plane of the wall is less than $(\sqrt{f_{ck}}/12)A_{cu}$, horizontal reinforcement at the edges of structural walls without boundary elements shall have a standard hook engaging the edge reinforcement or the edge reinforcement shall be enclosed in U-stirrups with the same diameter and spacing as the horizontal reinforcement.

$(\sqrt{f_{ck}}/12)A_{cu}$ [illegible]소가 없는 구 [illegible]근을 수평철 [illegible]아주거나 수평 U형 스터럽

0520.7.6.6 Splices of reinforcement

For longitudinal reinforcement of the boundary element, mechanical and welded splices shall satisfy 0520.1.5.4 and 0520.1.5.5, respectively.

0520.7.7 Coupling beams

0520.7.7.1 For coupling beams with $l_n/h \geq 4$

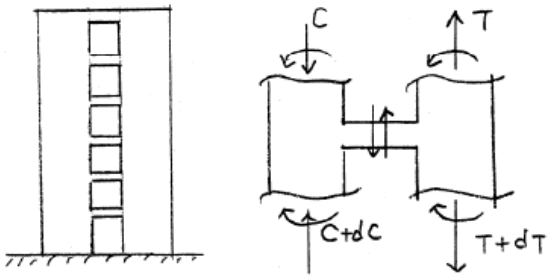
For coupling beams with a slenderness ratio of $l_n/h \geq 4$, the requirements of 0520.4 shall be satisfied. If it is demonstrated by analysis that the beam has adequate lateral stability, the requirements of 0520.4.1.2(3) and 0520.4.1.2(4) need not be satisfied.

0520.7.7.2 For coupling beams with $l_n/h < 4$

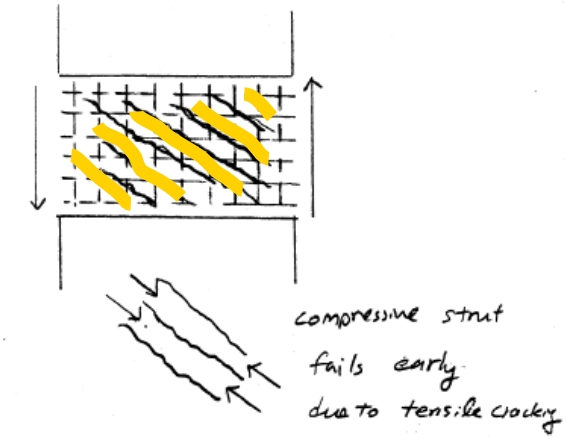
Coupling beams with a slenderness ratio of $l_n/h < 4$ shall be permitted to be reinforced with two intersecting groups of diagonally-placed bars symmetrical about the mid-span. If an alternative method having the performance equal to or exceeding that provided by the two intersecting groups of diagonally-placed bars is used, its performance shall be verified in accordance with 0211.

0520.7.7.3 Design of two intersecting groups of diagonally-placed bars

Unless it can be shown that loss of stiffness and strength of the coupling beams will not impair the vertical load-carrying capacity of the structure, the egress from the structure, or the integrity of nonstructural components and their connections to the structure, coupling beams with an aspect ratio of $l_n/h < 2$ and with a factored shear force of $V_u > (\sqrt{f_{ck}}/3)A_{cp}$ shall be reinforced with two intersecting groups of diagonally-placed bars symmetrical about the mid-span. The groups of diagonal bars shall be permitted to contribute to the nominal moment strength of the coupling beam.



large shear force is induced in coupling beam.



절차에 따라 성능검증이 이루어져야 한다.

0520.7.7.3 대각선 다발철근 설계

if $l_n/d < 2$, $V_u > \frac{1}{3}\sqrt{f'_c}\, b_w d$

diagonal reinforcement is required

일체성 능이 저해되지 않는다는 사실을 입승할 수 없으면, 세장비가 $l_n/h < 2$이고 계수전단력이 $V_u > (\sqrt{f_{ck}}/3)A_{cp}$인 연결보는 경간 중앙에 대하여 대칭인 대각선철근묶음으로 설계하여야 한다. 이 대각선 다발철근은 연결보의 공칭휨강도에 기여하는 것으로 볼 수 있다.

0520.7.7.4 Details of groups of diagonal bars

Coupling beams reinforced with two intersecting groups of diagonally-placed bars symmetrical about the mid-span shall satisfy the following (1) and (2), and either (3) or (4).

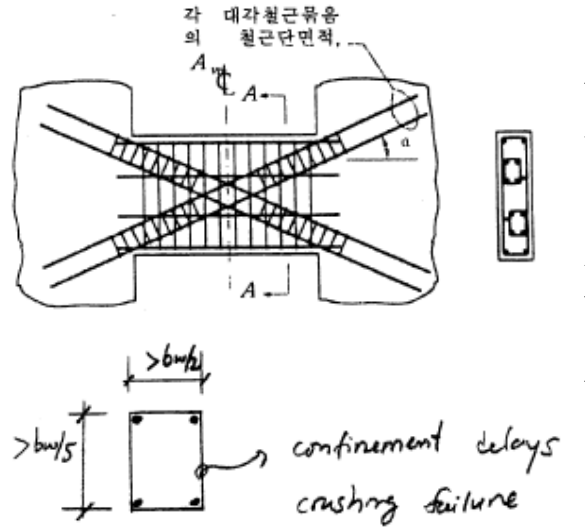
(1) Each group of diagonal bars shall consist of at least 4 bars, and each diagonal bar shall be developed into the wall at least 1.25 times the development length for the specified yield strength in tension.

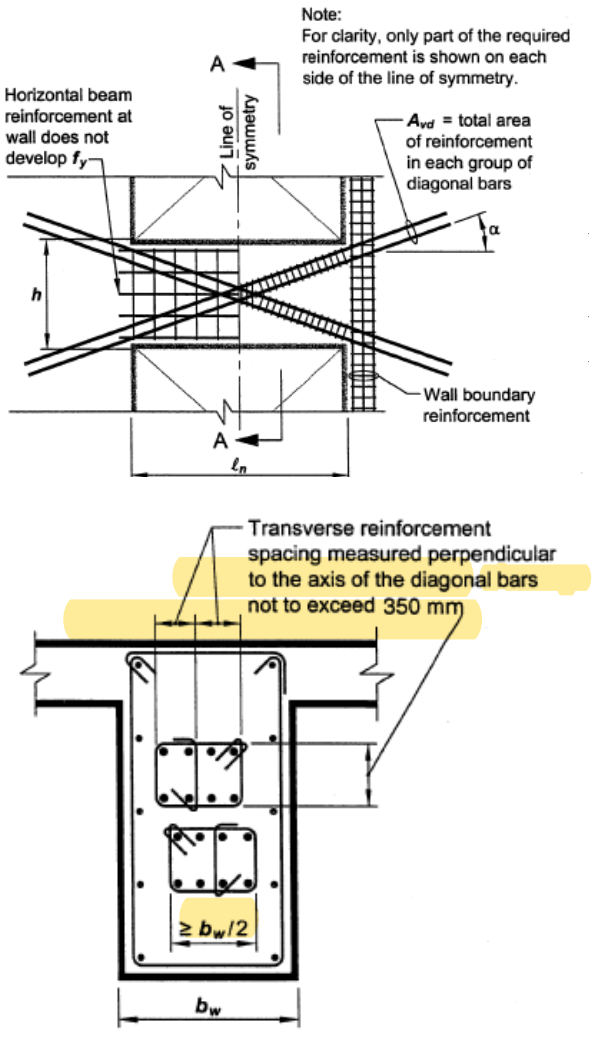
(2) The nominal shear strength V_n shall be calculated by Eq. (0520.7.3).

$$V_n = 2A_{vd} f_y \sin\alpha \le (5\sqrt{f_{ck}}/6)A_{cp} \qquad (0520.7.3)$$

(3) Each group of diagonal bars shall be enclosed by transverse reinforcement satisfying 0520.5.4.1, 0520.5.4.2, 0520.5.4.3, and Eq. (0520.5.5). Also, spacing of transverse reinforcement shall not exceed 6 times the diameter of the diagonal bar. To calculate A_g for Eqs. (0506.4.1) and (0520.5.3), the minimum concrete cover as required by 0505.4 shall be assumed on all four sides of each group of diagonal bars. Out-to-out dimensions of transverse reinforcement enclosing diagonal bars shall not be less than $b_w/2$ in the direction parallel to b_w and $b_w/5$ in the direction perpendicular to diagonal bars within the beam plane. The area of reinforcement, which is transverse and parallel to the longitudinal direction of a coupling beam, shall not be less than $0.002 b_w s$ in each direction, and spacing shall not exceed 300 mm.

(4) For the beam cross-section satisfying 0520.5.4.1 and 0520.5.4.3, spacing of transverse reinforcement shall not exceed the lesser of 150 mm and 6 times the diameter of diagonal bars. Spacing of cross-ties both vertically and horizontally in the plane of the





어야 한다. 각 연결철근과 횡보강근의 철고더

beam cross-section shall not exceed 200 mm. Each cross-tie and hook of transverse bars shall engage a longitudinal bar of equal or greater diameter, and mechanical anchor bars shall be permitted to be used as cross-ties. It shall be permitted to configure transverse reinforcement as specified in 0520.4.3.6.

0520.7.8 Construction joints

All construction joints in structural walls shall conform to Concrete Standard Specification, and contact surfaces shall be roughened in accordance with 0507.7.3(1).

0520.7.9 Discontinuous walls

Columns supporting discontinuous structural walls shall be reinforced in accordance with 0520.5.4.5.

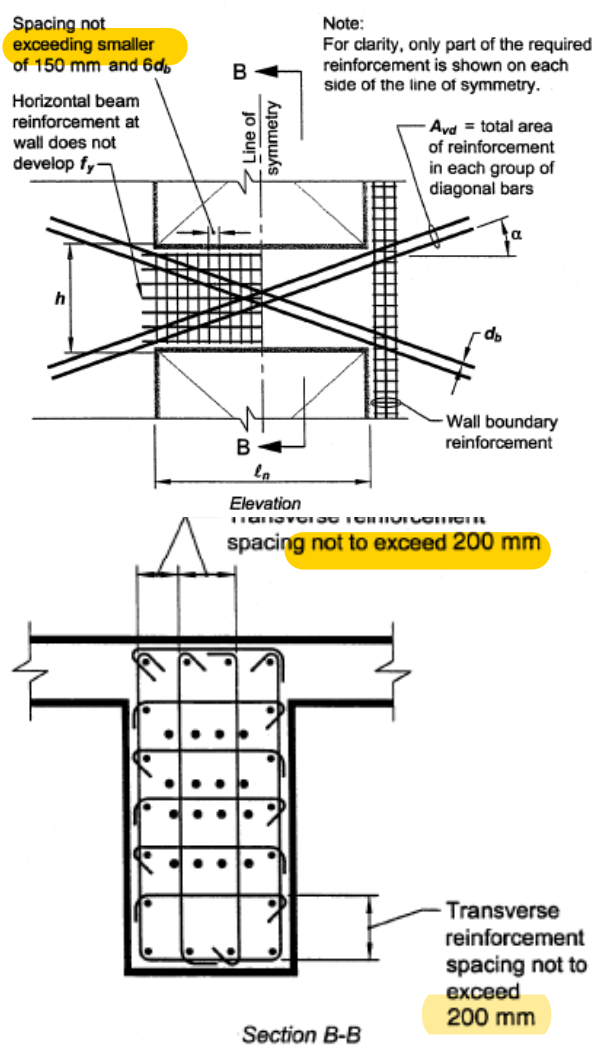
0520.8 Structural diaphragms and trusses

0520.8.1 Scope

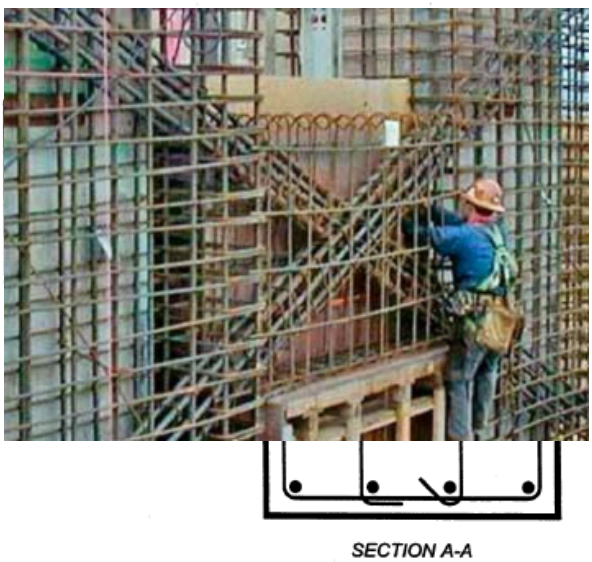
Floor and roof slabs acting as structural diaphragms to transmit earthquake forces shall be designed in accordance with this section. This section shall apply to trusses forming part of the seismic-force-resisting system and struts, connecters, chords, and collectors transmitting loads induced by earthquake motions.

0520.8.2 Cast-in-place composite topping slab diaphragms

A cast-in-place composite topping slab on a precast floor or roof shall be permitted to be used as a structural diaphragm, provided the cast-in-place topping slab is reinforced and the surface of the previously hardened concrete on which the topping slab is placed is clean, free of laitance, and intentionally roughened.



다. 이 절의 규정은 횡력저항 시스템의 일부로 작용하는 트러스와 지진으로 발생하는 하중을 전달하는 버팀부재, 연결부재, 현부재 및 수집부재에



0520.8.3 Cast-in-place topping slab diaphragms

If a cast-in-place topping slab is designed and detailed to independently resist the design earthquake forces, composite action between the topping slab and the precast floor element shall not be required.

0520.8.4 Minimum thickness of diaphragms

0520.8.4.1 Concrete slabs and composite topping slabs

The thickness of concrete slabs and composite topping slabs acting as structural diaphragms used to transmit earthquake forces shall not be less than 50 mm.

0520.8.4.2 Cast-in-place topping slabs on precast floors or roofs

The thickness of topping slabs placed over precast floor or roof elements, which act as structural diaphragms but do not rely on composite action with the precast elements to resist the design earthquake forces, shall not be less than 65 mm.

0520.8.5 Reinforcement

0520.8.5.1 Minimum reinforcement ratio

The minimum reinforcement ratio for structural diaphragms shall be in accordance with 0505.7. Spacing of reinforcement each way in floor or roof systems shall not exceed 450 mm, except for post-tensioned slabs. Where welded wire reinforcement is used as the distributed reinforcement to resist shear in topping slabs placed over precast floor and roof elements, the wires parallel to the span of the precast elements shall be spaced not less than 250 mm on center. Reinforcement provided for shear strength shall be continuous and shall be distributed uniformly across the shear plane.

적용하여야 한다.

0520.8.2 현장치기 복합-덧치기 슬래브 격막

덧치기 슬래브를 철근으로 보강하고, 연결부가 현부재, 수집부재 그리고 횡력 저항 시스템에 하중을 완전하게 전달할 수 있도록 설계한다면, 프리캐스트콘크리트 바닥 또는 지붕의 현장치기 복합 덧치기 슬래브는 격막으로 사용할 수 있다. 덧치기를 할 때 기존 콘크리트 면은 깨끗하고 레이턴스가 없어야 하며, 의도적으로 거칠게 하여야 한다.

0520.8.3 현장치기 덧치기 슬래브 격막

현장치기 덧치기 슬래브를 독자적으로 설계지진력에 저항하도록 설계하면, 덧치기 슬래브와 프리캐스트콘크리트 바닥 요소와의 복합작용은 요구되지 않는다.

0520.8.4 격막의 최소두께

0520.8.4.1 콘크리트 슬래브와 복합덧치기 슬래브

지진력을 전달하기 위해 사용되는 구조격막으로 작용하는 콘크리트 슬래브와 복합 덧치기 슬래브의 두께는 50 mm 이상이어야 한다.

0520.8.4.2 프리캐스트콘크리트 바닥 또는 지붕 현장치기 슬래브

프리캐스트콘크리트 바닥 또는 지붕의 덧치기 슬래브로서 구조격막으로는 작용하지만 지진하중에 저항하기 위한 프리캐스트콘크리트 부재와의 복합성능에 의존하지 않는 경우의 슬래브두께는 65 mm 이상이어야 한다.

0520.8.5 철근

0520.8.5.1 최소철근비

구조격막에 대한 최소철근비는 0505.7을 따라야

0520.8.5.2 Reinforcement in chords or collectors of diaphragms

Bonded tendons used as reinforcement in chords or collectors of diaphragms shall be designed so that the stress due to design earthquake forces does not exceed 420 MPa. If a seismic load path is provided, precompression from unbonded tendons shall be permitted to resist diaphragm design forces.

0520.8.5.3 Details of structural trusses, struts, connecters, chords, and collectors

Structural truss elements, struts, connecters, chords, and collectors with compressive stresses exceeding $0.2f_{ck}$ at any section shall have transverse reinforcement satisfying 0520.5.4.1, 0520.5.4.2, and 0520.5.4.3 over the length of the elements. The specified transverse reinforcement shall be permitted to be discontinued at a section where the calculated compressive stress is less than $0.15f_{ck}$. The compressive stress shall be calculated for the factored forces using a linearly elastic model based on the gross section of the elements considered.

0520.8.5.4 Splices and development of continuous reinforcement

All continuous reinforcement in diaphragms, trusses, struts, connecters, chords, and collectors shall be spliced or developed in accordance with 0520.6.4 for the specified yield strength in tension.

0520.8.5.5 Splices of vertical members

Type 2 splices specified in 0520.1.5.4(1) shall be used where mechanical splices are used to transfer forces between the diaphragm and the vertical members of the seismic-force-resisting system.

한다. 포스트텐션이 되지 않은 바닥이나 지붕 시스템의 철근 간격은 각 방향으로 450 mm 이하이어야 한다. 프리캐스트 바닥과 지붕의 덧치기 슬래브에서 전단력을 저항하도록 용접철망을 사용하는 경우에 프리캐스트 부재의 경간에 평행한 철선의 간격은 250 mm 이상이어야 한다. 전단강도를 위하여 배치된 철근은 연속이어야 하고 전체 단면에 대하여 균등하게 분포시켜야 한다.

0520.8.5.2 격막의 현부재 또는 수집부재의 보강근

격막의 현부재 또는 수집부재에서 주 보강근으로 사용된 부착 긴장재는 설계지진력에 의한 응력이 420 MPa를 초과하지 않도록 크기 및 배치를 적절하게 결정하여야 한다. 지진 하중경로가 확보된다면, 비부착 긴장재에 의해 발생하는 사전 압축은 격막 설계력을 저항하는데 허용될 수 있다.

0520.8.5.3 구조 트러스부재, 버팀부재, 연결부재, 격막의 현부재 및 수집부재의 요구상세

구조트러스부재, 버팀부재, 연결부재, 격막의 현부재 및 수집부재는 임의의 단면에서 $0.2f_{ck}$를 초과하는 압축응력을 받을 때 부재의 전 길이에 걸쳐서 0520.5.4.1, 0520.5.4.2, 0520.5.4.3의 규정에 의한 특수 횡방향 철근을 배치하여야 한다. 특수 횡방향 철근은 압축응력이 $0.15f_{ck}$ 미만으로 계산되는 위치에서 중단할 수 있다. 압축응력은 구조부재의 전 단면을 고려한 선형 탄성 모델에 의해 계수하중에 대해 계산하여야 한다.

0520.8.5.4 연속철근의 이음과 정착

격막, 트러스, 버팀부재, 연결부재, 현부재 및 수

0520.8.6 Design forces

The earthquake design forces for diaphragms shall be permitted to be obtained by the lateral-force analysis for design load combinations.

0520.8.7 Shear strength

0520.8.7.1 Nominal shear strength of structural diaphragms

Nominal shear strength V_n of structural diaphragms shall not exceed the value calculated by Eq. (0520.8.1).

$$V_n = A_{cv}(\frac{\sqrt{f_{ck}}}{6} + \rho_n f_y) \quad (0520.8.1)$$

0520.8.7.2 Nominal shear strength of cast-in-place composite topping slab diaphragms on precast floor or roof elements

Nominal shear strength V_n of cast-in-place composite and noncomposite topping slab diaphragms on precast floor or roof elements shall not exceed the value calculated by Eq. (0520.8.2).

$$V_n = A_{cv}\rho_n f_y \quad (0520.8.2)$$

where, A_{cv} is based on the topping slab thickness. The required web reinforcement shall be uniformly distributed over the entire section in both directions .

집부재 등의 모든 연속철근은 0520.6.4의 인장철근의 규정에 따라 이음 또는 정착시켜야 한다.

0520.8.5.5 수직 요소의 철근의 이음

격막과 횡력저항시스템의 수직 요소 사이에 하중을 전달하기 위하여 기계적이음을 사용할 때는 0520.1.5.4(1)의 유형 2의 이음으로 하여야 한다.

0520.8.6 설계하중

구조격막에 대한 설계지진력은 설계하중 조합에 따른 횡력 해석에 의하여 구할 수 있다.

0520.8.7 전단강도

0520.8.7.1 구조 격막의 공칭전단강도

구조 격막의 공칭전단강도 V_n은 식(0520.8.1)의 값 이하이어야 한다.

(0520.8.1)

0520.8.7.2 프리캐스트콘크리트 바닥 또는 지붕 현장치기 복합-덧치기 슬래브 격막의 공칭전단강도

프리캐스트콘크리트 바닥 또는 지붕 현장치기 복합-덧치기 슬래브 격막과 현장치기 덧치기 슬래브 격막의 공칭전단강도 V_n은 식(0520.8.2)의 값 이하이어야 한다.

(0520.8.2)

여기서, A_{cv}는 덧치기 슬래브의 두께에 근거한 값이다. 필요한 복부 보강근은 격막의 전단면에 양 방향으로 균등하게 분포되어야 한다.

0520.8.7.3 Nominal shear strength limit

Nominal shear strength shall not exceed $(2\sqrt{f_c}/3)A_{cu}$, where A_{cv} is the gross sectional area of the diaphragm.

0520.8.7.3 공칭전단강도의 제한

공칭전단강도는 $2(\sqrt{f_c}/3)A_{cv}$를 초과할 수 없다. 여기서, A_{cv}는 격막의 전체단면적이다.

0520.8.8 Boundary elements of structural diaphragms

0520.8.8 구조격막의 경계요소

0520.8.8.1 General

Boundary elements of a structural diaphragm shall be proportioned to resist the sum of the factored axial forces acting in the plane of the diaphragm and the load obtained by dividing the factored moment at the section by the distance between the boundary elements of the diaphragm at that section.

0520.8.8.1 일반사항

구조격막의 경계요소는 격막 면내에 작용하는 계수축력과 그 단면의 계수휨모멘트를 단면에서 격막의 경계 요소 사이의 거리로 나눈 값의 합력을 저항할 수 있도록 크기가 결정되어야 한다.

0520.8.8.2 Splices of reinforcement

Splices of tensile reinforcement in all diaphragm boundary elements and collectors shall develop the specified yield strength. Mechanical and welded splices shall conform to 0520.1.5.4 and 0520.1.5.5, respectively.

0520.8.8.2 철근의 이음

모든 격막의 경계요소 및 수집부재의 인장철근 이음은 철근의 설계기준항복강도를 발휘하도록 하여야 한다. 기계적이음과 용접이음은 각각 0520.1.5.4과 0520.1.5.5을 따라야 한다.

0520.8.8.3 Detailing of splices and anchorage zones

Longitudinal reinforcement detailing for chord and collector elements at splices and anchorage zones shall satisfy the following (1) or (2).

(1) Center-to-center spacing of at least three times longitudinal bar diameters, but not less than 40 mm, and concrete clear cover of at least two and one-half times longitudinal bar diameters, but not less than 50 mm.

(2) Transverse reinforcement required by 0507.4.3.3, except as required in 0520.8.5.3.

0520.8.8.3 이음과 정착부위의 요구상세

이음과 정착 부위에서 현부재와 수집부재의 주철근은 다음 중 하나를 확보하여야 한다.

(1) 축방향 주철근 지름의 3배 이상 및 40 mm 이상인 최소 중심간 거리와 축방향 주철근 지름의 2.5배 이상 및 50 mm 이상인 최소 콘크리트 피복두께

(2) 0520.8.5.3에 규정된 것을 제외한 0507.4.3.3 규정에 의해 요구되는 철근

0520.8.9 Construction joints

All construction joints in diaphragms shall

0520.8.9 시공줄눈

격막의 모든 시공줄눈은 콘크리트표준시방서에

conform to Concrete Standard Specification, and contact surfaces shall be roughened in accordance with 0507.7.3(1).

따라야 하며, 접합면은 0507.7.3.1에 규정된 바와 같이 거칠게 하여야 한다.

0520.9 Foundations

0520.9 기초

0520.9.1 Scope

0520.9.1 적용범위

Foundations resisting earthquake-induced forces or transferring earthquake-induced forces between the structure and ground shall be in accordance with 0520.9 and other applicable chapter provisions.

지진하중을 저항하거나 구조체와 지반 사이에 지진하중을 전달하는 기초는 0520.9의 조항과 관련된 적용 가능한 다른 기준도 따라야 한다.

0520.9.2 Footings, foundation mats, and pile caps

0520.9.2 기초판, 전면기초 및 말뚝캡

0520.9.2.1 General

0520.9.2.1 일반사항

Longitudinal reinforcement of columns and structural walls resisting forces induced by earthquake effects shall extend into the footing, mat, or pile cap, and shall be fully developed for tension at the interface.

지진하중에 저항하는 기둥과 구조벽체의 축방향 철근은 기초판, 전면기초 또는 말뚝캡까지 연장되어야 하며, 접합면에서 인장에 대하여 충분하게 정착되어야 한다.

0520.9.2.2 Columns designed assuming fixed-end conditions at foundation

0520.9.2.2 기초에서 고정단으로 가정되어 설계된 기둥

Columns designed assuming fixed-end conditions at the foundation shall comply with 0520.9.2.1. If hooks are required, longitudinal reinforcement resisting flexure shall have 90-degree hooks near the bottom of the foundation with the free end of the bars oriented toward the center of the column.

기초에서 고정단으로 가정되어 설계된 기둥은 0520.9.2.1을 따라야 한다. 표준갈고리가 필요한 경우에는, 휨모멘트에 저항하는 종방향 철근의 끝단이 기둥의 중심을 향하도록 하여 기초의 밑면에서 90° 표준갈고리로 설치하여야 한다.

0520.9.2.3 Columns or boundary elements of special reinforced concrete structural walls having edge within 1/2 of footing depth

0520.9.2.3 기초깊이의 1/2 이내에 연단이 있는 특수철근콘크리트구조벽체의 기둥 또는 경계요소

For columns or boundary members of special reinforced concrete structural walls that have an edge within 1/2 of the footing depth from an edge of the footing, transverse reinforcement in accordance with 0520.5.4 shall be provided below the top of the footing. The transverse reinforcement shall extend into the footing, mat,

기초의 연단부터 기초깊이의 1/2 이내에 연단이 있는 특수철근콘크리트 구조벽체의 기둥 또는 경계요소는 0520.5.4에 따라 기초의 상단 아래로 횡방향 철근을 설치하여야 한다. 이 철근은 기초판, 전면기초 또는 말뚝캡으로 연장되어야 하며, 인장력에 대해 f_y를 발휘할 수 있도록 정착하여야 한다.

or pile cap, and shall be developed for f_y in tension.

0520.9.2.4 Members with uplift forces

Where earthquake effects create uplift forces in boundary elements of special reinforced concrete structural walls or columns, flexural reinforcement shall be provided in the top of the footing, mat, or pile cap to resist the design loads, and the flexural reinforcement shall satisfy 0506.3.2.

0520.9.2.4 양압력이 발생하는 부위의 부재

특수철근콘크리트 구조벽체의 경계요소 또는 기둥에서 지진의 영향으로 양압력이 발생하는 곳에서는 설계하중에 저항할 수 있도록 휨철근이 기초, 전면기초, 말뚝캡의 상부에 배치되어야 하며, 이 휨철근은 0506.3.2의 규정을 만족하여야 한다.

0520.9.2.5 Structural plain concrete in footings and basement walls

Usage of structural plain concrete in footings and basement walls shall be in accordance with 0519.

0520.9.2.5 기초와 지하실 벽체의 무근콘크리트 사용

기초와 지하실 벽체의 무근콘크리트 사용은 0519를 참조하여야 한다.

0520.9.3 Grade Beams and Slab-on-ground

0520.9.3 지중보와 지면 슬래브

0520.9.3.1 Development of longitudinal reinforcement in grade beams

Grade beams, which are designed to act as horizontal ties between pile caps or footings, shall have continuous longitudinal reinforcement. The longitudinal reinforcement shall be developed within or beyond the supported column, and shall be anchored within the pile cap or footing at all discontinuities.

0520.9.3.1 지중보의 종방향철근의 정착

말뚝캡 또는 기초 사이를 수평 연결재로서 거동하도록 설계되는 지중보는 연속적인 종방향 철근을 배치하여야 한다. 이 철근은 지지기둥 내에, 또는 통과하여 정착길이가 확보되어야 하며, 모든 불연속에서 말뚝캡 또는 기초 내에 정착되어야 한다.

0520.9.3.2 Size of grade beams and spacing of closed ties

Grade beams, which are designed to act as horizontal ties between pile caps or footings, shall be sized so that the smallest cross-sectional dimension is not less than the clear spacing between connected columns divided by 20 but not greater than 450 mm. Spacing of closed ties shall not exceed the lesser of one-half the smallest orthogonal cross-sectional dimension and 300 mm.

0520.9.3.2 지중보의 단면치수와 폐쇄형 띠철근 간격

말뚝캡 또는 기초사이를 수평연결재로서 거동하도록 설계되는 지중보의 최소 단면 치수는 연결된 기둥의 순경간을 20으로 나눈 값 이상이어야 하나, 450 mm보다 클 필요는 없다. 폐쇄띠철근의 간격은 직교된 단면 중 작은 치수의 1/2 이하 또한 300 mm 이하이어야 한다.

0520.9.3.3 Grade beams subjected to flexure

0520.9.3.3 휨모멘트를 전달받는 지중보

Grade beams and beams, which are part of a mat foundation subjected to flexure from columns which are part of the seismic-force-resisting system, shall be in accordance with 0520.4.

횡저항 시스템의 일부인 기둥에서 휨모멘트를 전달받는 전면기초의 일부인 보와 지중보는 0520.4를 따라야 한다.

0520.9.3.4 Slab-on-ground resisting earthquake forces

Slab-on-ground, which resists earthquake forces from walls or columns that are part of the seismic-force-resisting system, shall be designed as structural diaphragms in accordance with 0520.8. The structural drawing shall clearly indicate that the slab-on-ground is a structural diaphragm and part of the seismic-force-resisting system.

0520.9.3.4 지진력을 저항하는 지면슬래브

횡저항 시스템의 일부인 벽체나 기둥에서 전달되는 지진력을 저항하는 지면슬래브는 0520.8의 구조격막으로 설계하여야 한다. 구조도면은 지면슬래브가 구조격막이며 횡저항 시스템임을 명확하게 언급하여야 한다.

0520.9.4 Piles, piers, and caissons

0520.9.4 말뚝, 교각 및 케이슨

0520.9.4.1 Scope

This section shall apply to concrete piles, piers, and caissons supporting earthquake-resistant structures.

0520.9.4.1 적용범위

이 절은 내진설계된 구조물을 지지하는 콘크리트 말뚝, 교각 및 케이슨에 적용하여야 한다.

0520.9.4.2 Piles, piers, and caissons resisting tension loads

For piles, piers, and caissons resisting tension loads, continuous longitudinal reinforcement shall be provided over the length resisting design tension forces. The longitudinal reinforcement shall be detailed to transfer tension forces within the pile cap to supported structural members.

0520.9.4.2 인장력에 저항하는 말뚝, 교각 및 케이슨

인장력에 저항하는 말뚝, 교각 및 케이슨은 설계인장력을 저항하는 전 구간에 걸쳐 연속적인 종방향 철근을 확보하여야 한다. 종방향 철근은 말뚝캡 내부의 인장력을 지지 구조 부재에 전달할 수 있는 상세를 가져야 한다.

0520.9.4.3 Pile top reinforcement transferring tension forces

Where tension forces induced by earthquake effects are transferred between the pile cap or mat foundation and precast pile by reinforcement grouted or post-installed in the top of the pile, the grouting system shall be demonstrated by test to develop at least 125% of the design

0520.9.4.3 인장력이 말뚝의 상단에 설치된 보강근에 의해 전달되는 경우

지진에 의하여 발생된 인장력이 말뚝캡 또는 전면기초와 프리캐스트콘크리트 말뚝 사이에서 말뚝의 상단에 설치된 보강근에 의해 전달되는 경우에 그라우트 시스템은 최소한 철근의 설계기준 항복강도의 125%까지 도달할 수 있다는 것을 시험에 의하여 확인하여야 한다.

specified yield strength of the bar.

0520.9.4.4 Transverse reinforcement of piles, piers, and caissons

For piles, piers, and caissons, transverse reinforcement in accordance with 0520.5.4 shall be provided at the locations of (1) and (2).

(1) At the top of the member, at least 5 times the member cross-sectional dimension, but not less than 2 m below the bottom of the pile cap

(2) For the portion of piles in soil that is not capable of providing lateral support or exposed to air and water, along the entire unsupported length plus the length required in (1)

0520.9.4.4 말뚝, 교각 및 케이슨의 철근배근 상세

말뚝, 교각 및 케이슨은 아래의 (1)와 (2)의 위치에서 0520.5.4를 따라 횡방향 철근을 배치하여야 한다.

(1) 부재 상단에서 단면 치수의 최소 5배, 그러나 말뚝캡의 밑면에서 2m 이상의 길이에 해당하는 부재의 상부

(2) 횡지지를 제공할 수 없는 토질 또는 공기 중과 수중에 노출된 말뚝의 경우, 전체 비지지 길이에 (1)에서 요구하는 길이를 더한 길이

0520.9.4.5 Precast concrete driven piles

For precast concrete driven piles, the length where transverse reinforcement is provided shall be sufficient to consider the potential variations in the elevation of pile tips.

0520.9.4.5 프리캐스트 항타말뚝

프리캐스트콘크리트 항타말뚝의 경우, 횡철근의 구간은 말뚝단부의 높이 변화 가능성을 고려하여 횡방향 철근의 배근 구간을 충분히 확보하여야 한다.

0520.9.4.6 Concrete piles, piers, and caissons in foundations supporting short and wide bearing walls

For concrete piles, piers, and caissons in foundations supporting short and wide bearing walls with one or two stories, transverse reinforcement need not satisfy 0520.9.4.4 and 0520.9.4.5.

0520.9.4.6 낮고 폭이 넓은 내력벽체를 지지하는 기초의 콘크리트 말뚝, 피어 및 케이슨

1개 층 또는 2개 층의 낮고 폭이 넓은 내력벽체를 지지하는 기초의 콘크리트말뚝, 교각 및 케이슨은 0520.9.4.4와 0520.9.4.5의 횡철근 요구사항을 만족시키지 않아도 된다.

0520.9.4.7 Pile caps incorporating batter piles

Pile caps incorporating batter piles shall be designed to resist the full compressive strength of the batter piles acting as short columns. For the portion of the piles in soil that is not capable of providing lateral support or exposed to air or water, slenderness effects of the batter piles shall be considered.

0520.9.4.7 항타말뚝을 통합한 말뚝캡

경사말뚝을 포함한 말뚝캡은 항타 경사말뚝을 단주로 가정할 때의 압축강도에 저항하도록 설계되어야 한다. 횡력을 제공할 수 없는 토질 또는 공기와 수중에 노출된 말뚝의 구간에 대해서 항타말뚝의 세장비효과를 고려하여야 한다.

Terminate all required top and bottom bars at the far face of the column core, providing min. distances, ℓ_{dh} or ℓ_d, for tension per Section A.6.4. or compression per Section 12.3, ACI 318-83

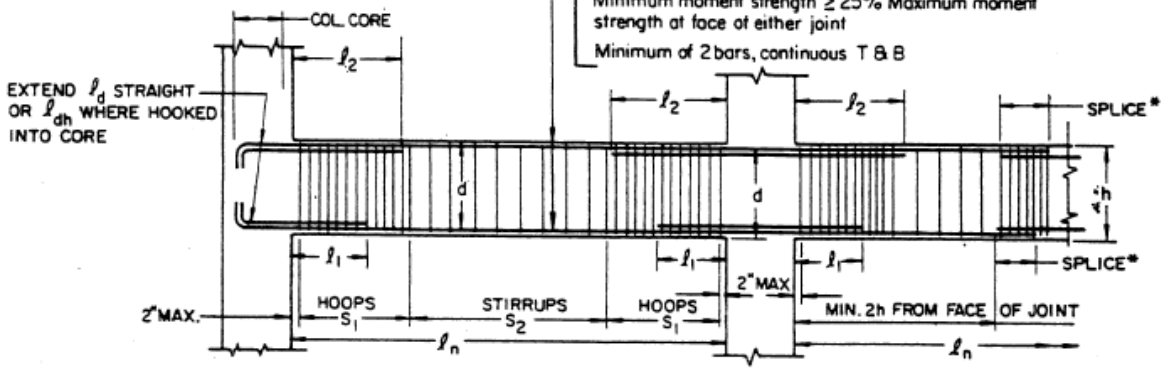
Longitudinal Reinforcement, Top and Bottom

Minimum $A_s \geq 200 b_w d/f_y$ $1.4 b_w d/f_y$

Maximum $\rho \leq 0.025$

Minimum moment strength ≥ 25% Maximum moment strength at face of either joint

Minimum of 2 bars, continuous T & B



Engineer must provide dimensions ℓ_1, ℓ_2, S_1, S_2, hoop and stirrup spacing, anchorage length, cut-off points of discontinuous bars, ℓ_d, or ℓ_{dh} if less then across column core.

$\ell_n \geq 4d$

ℓ_1 = distance required by design for moment plus anchorage length

ℓ_2 = distance to point of inflection plus anchorage length

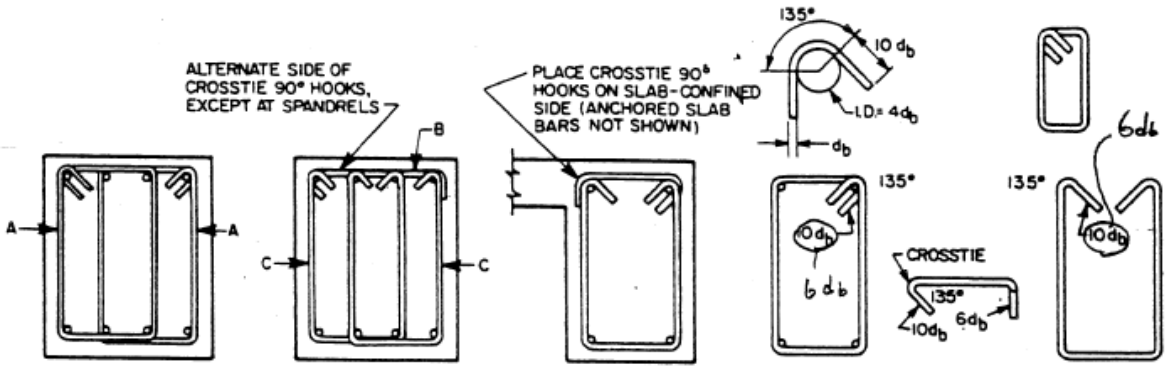
d = design depth for −M and +M

Maximum Hoop/Tie Spacings

In length S_1, spacing for hoops ≤ d/4; $8d_b$ of smallest bar; $24d_b$ of hoop; or 12 in.

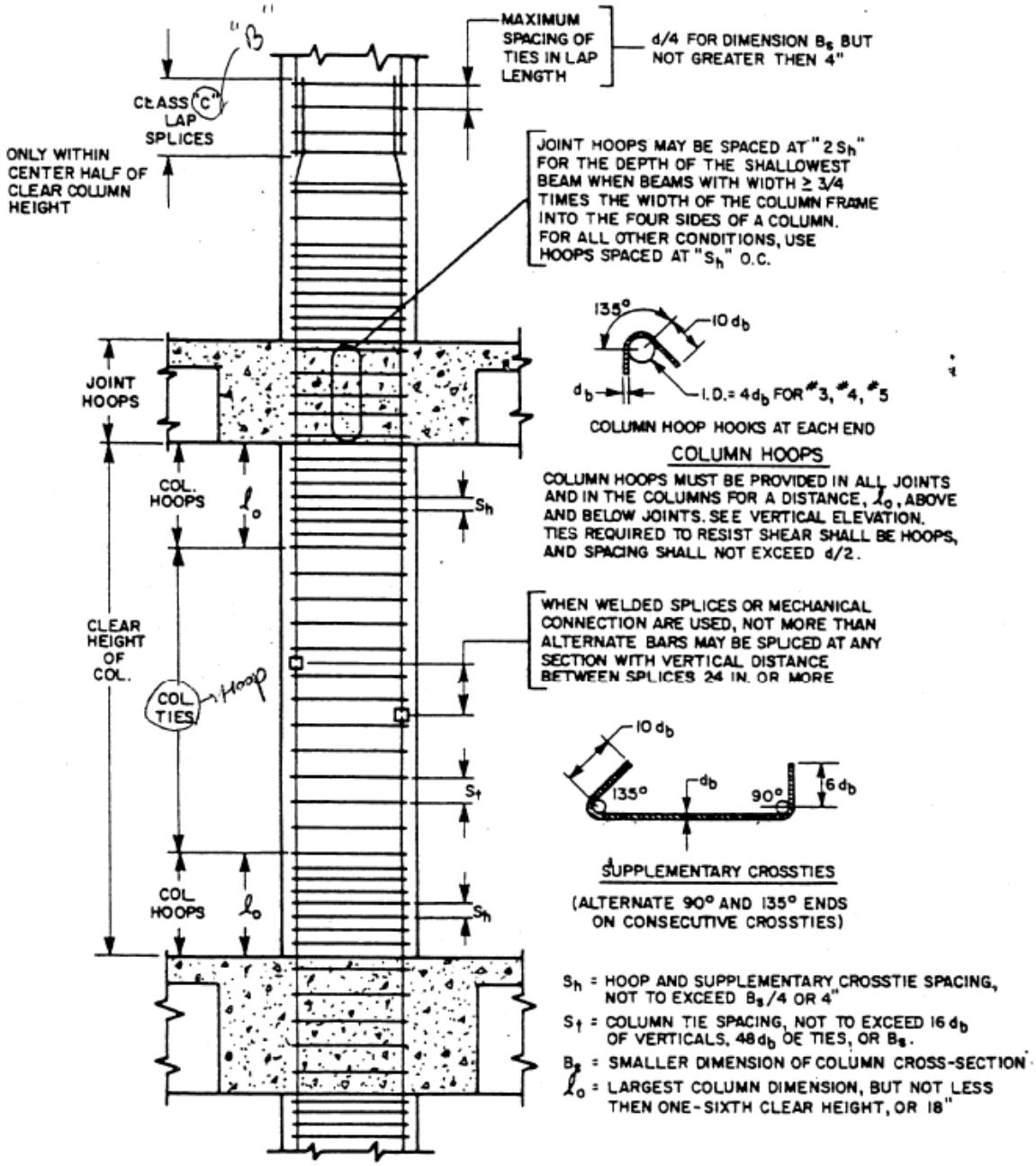
*At lap splices, spacing of hoops ≤ d/4 but not greater than 4 in.

In length S_2, spacing strirrups ≤ d/2



EXAMPLES OF OVER-LAPPING HOOPS | SPANDREL BEAM | DETAIL-A | DETAIL-B | DETAIL-C

STIRRUPS REQUIRED TO RESIST SHEAR SHALL BE HOOPS. THROUGHOUT THE LENGTH OF FLEXURAL MEMBERS WHERE HOOPS ARE NOT REQUIRED, STIRRUPS SHALL BE SPACED AT NO MORE THE d/2


"B"
CLASS "C" LAP SPLICES
ONLY WITHIN CENTER HALF OF CLEAR COLUMN HEIGHT
MAXIMUM SPACING OF TIES IN LAP LENGTH
d/4 FOR DIMENSION B_s BUT NOT GREATER THEN 4"
JOINT HOOPS MAY BE SPACED AT "2 S_h" FOR THE DEPTH OF THE SHALLOWEST BEAM WHEN BEAMS WITH WIDTH ≥ 3/4 TIMES THE WIDTH OF THE COLUMN FRAME INTO THE FOUR SIDES OF A COLUMN. FOR ALL OTHER CONDITIONS, USE HOOPS SPACED AT "S_h" O.C.
JOINT HOOPS
COL. HOOPS
l_o
S_h
CLEAR HEIGHT OF COL.
COL TIES
Hoop
S_t
COL HOOPS
l_o
S_h
WHEN WELDED SPLICES OR MECHANICAL CONNECTION ARE USED, NOT MORE THAN ALTERNATE BARS MAY BE SPLICED AT ANY SECTION WITH VERTICAL DISTANCE BETWEEN SPLICES 24 IN. OR MORE
135°
10 d_b
d_b
I.D. = 4 d_b FOR #3, #4, #5
COLUMN HOOP HOOKS AT EACH END
COLUMN HOOPS
COLUMN HOOPS MUST BE PROVIDED IN ALL JOINTS AND IN THE COLUMNS FOR A DISTANCE, l_o, ABOVE AND BELOW JOINTS. SEE VERTICAL ELEVATION. TIES REQUIRED TO RESIST SHEAR SHALL BE HOOPS, AND SPACING SHALL NOT EXCEED d/2.
10 d_b
135°
d_b
90°
6 d_b
SUPPLEMENTARY CROSSTIES
(ALTERNATE 90° AND 135° ENDS ON CONSECUTIVE CROSSTIES)
S_h = HOOP AND SUPPLEMENTARY CROSSTIE SPACING, NOT TO EXCEED B_s/4 OR 4"
S_t = COLUMN TIE SPACING, NOT TO EXCEED 16 d_b OF VERTICALS, 48 d_b OF TIES, OR B_s.
B_s = SMALLER DIMENSION OF COLUMN CROSS-SECTION
l_o = LARGEST COLUMN DIMENSION, BUT NOT LESS THEN ONE-SIXTH CLEAR HEIGHT, OR 18"