Week 12
Bridge (1)

457.308 Construction Methods and Equipment

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History of Bridge Development

Natural Bridges

Clapper Bridge

- Tree trunk
- Stone

700 A.D. Asia

Great Stone Bridge in China

- Low Bridge
- Shallow Arch

Circular segment
First open-spandrel w/ two small side arches:
- lighter weight
- flood control

(1) Install forms
(2) Build tapered stones above the forms

Roman Arch Bridge

- The Arch
- Natural Cement

100 B.C. Romans

- Strength of Materials
- Mathematical Theories
- Development of Metal

1300 A.D. Renaissance

History of Bridge Development

1800 A.D.

First Cast-Iron Bridge

Coalbrookdale, England

1850 A.D.

Britannia Tubular Bridge

- Wrought Iron

1900 A.D.

Truss Bridges

- Mechanics of Design

Suspension Bridges

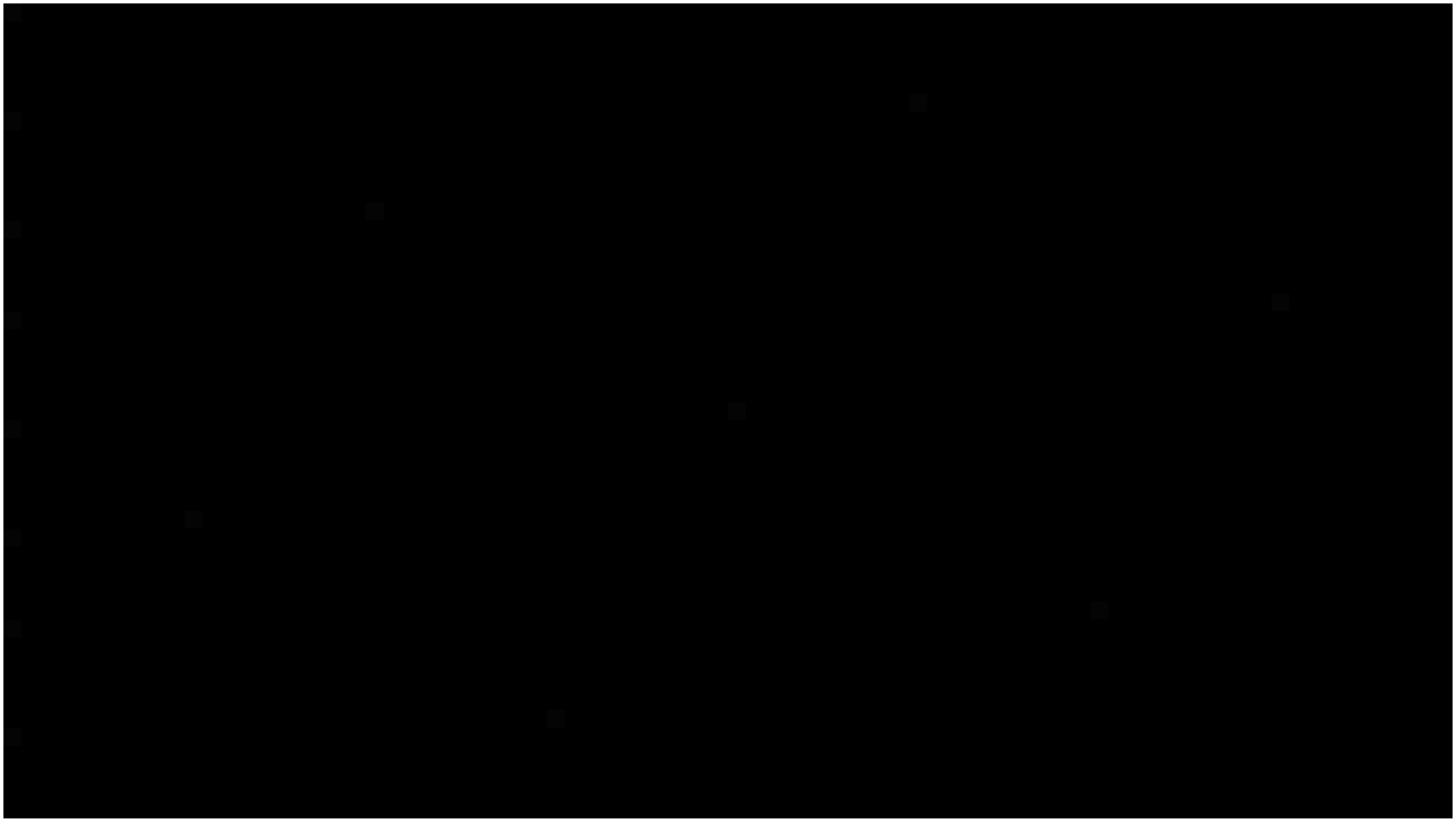
- Use of Steel for the suspending cables

1920 A.D.

2000 A.D.

- Prestressed Concrete
- Steel

Bahrain's North Manama Causeway

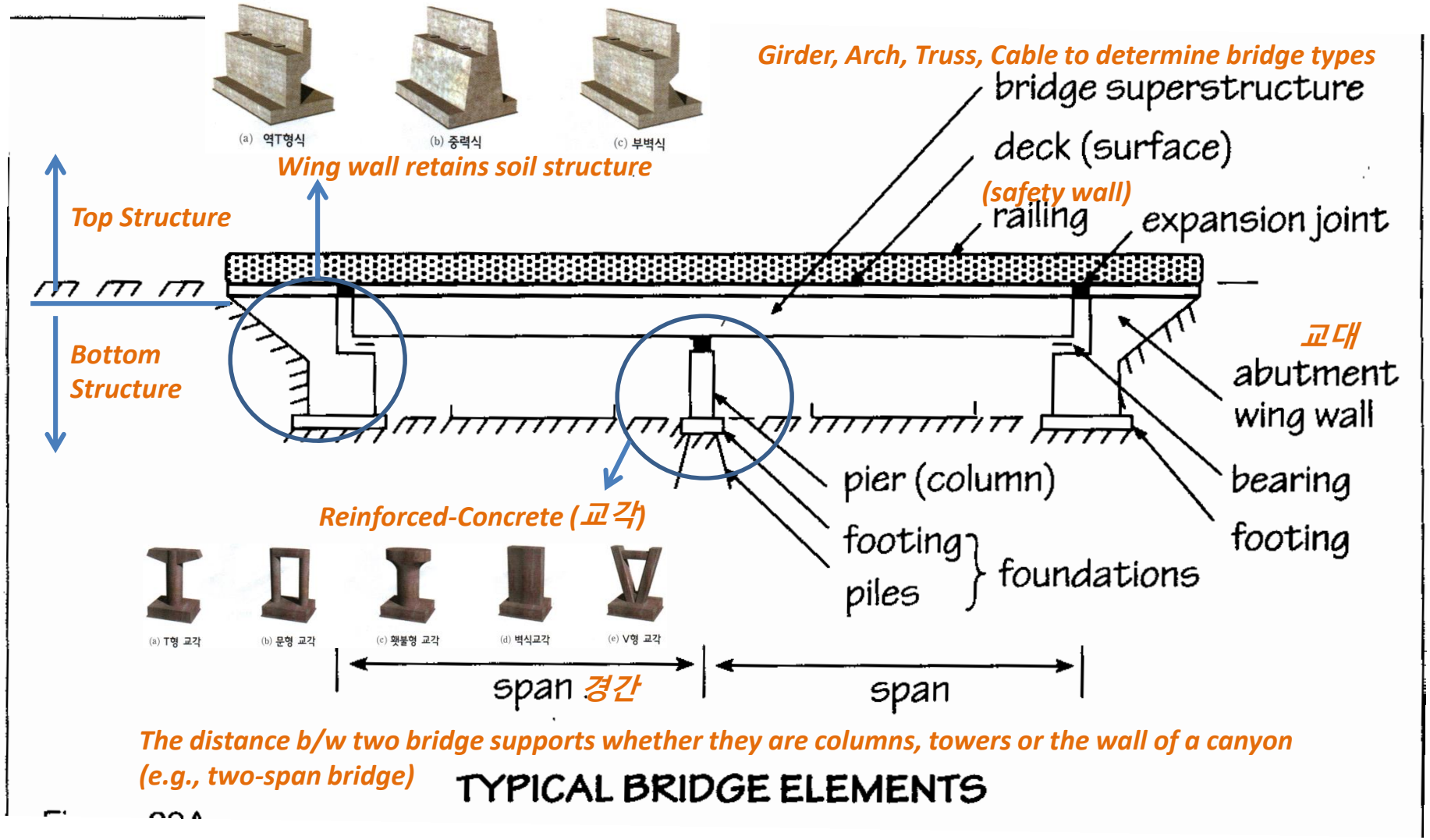


How Bridges Work?

"Every passing vehicle shakes the bridge up and down, making waves that can travel at hundreds of kilometers per hour. Luckily the bridge is designed to damp them out, just as it is designed to ignore the efforts of the wind to turn it into a giant harp. A bridge is not a dead mass of metal and concrete: it has a life of its own, and understanding its movements is as important as understanding the static forces."

Basic Structure

ABUTMENT
Bearing to load of the top structure and acting as a retaining wall to soils



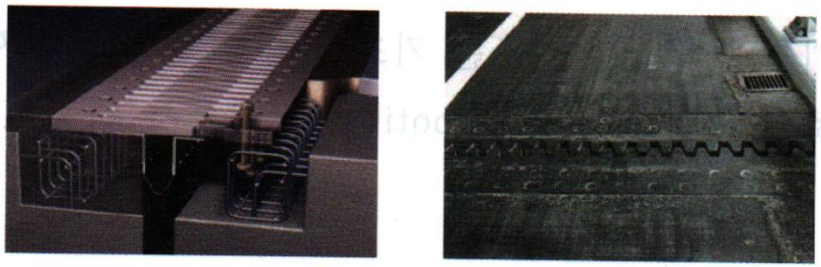
The distance b/w two bridge supports whether they are columns, towers or the wall of a canyon (e.g., two-span bridge)

TYPICAL BRIDGE ELEMENTS

Basic Structure

- **Bearing (교좌장치)**
  - Transit loads from the top structure to the bottom structure
  - Resist to earthquake, wind (horizontal vibration), temperature changes (expansion and deflection/displacement)

- **Expansion joint (신축이음장치)**
  - Placing gaps to prepare for concrete expansion by temperature changes, concrete creep, dry shrinkage, and live load
  - Finger type and Rail type (이음새 고무 용착)

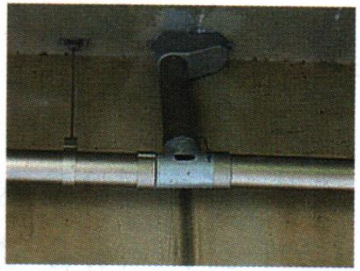


(a) finger type

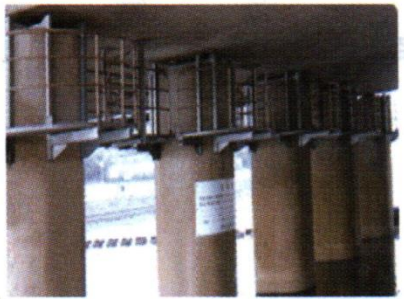
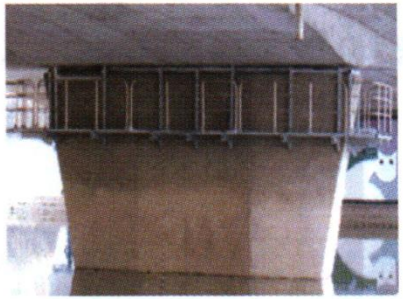
(b) rail type

Basic Structure

- Drainage facility

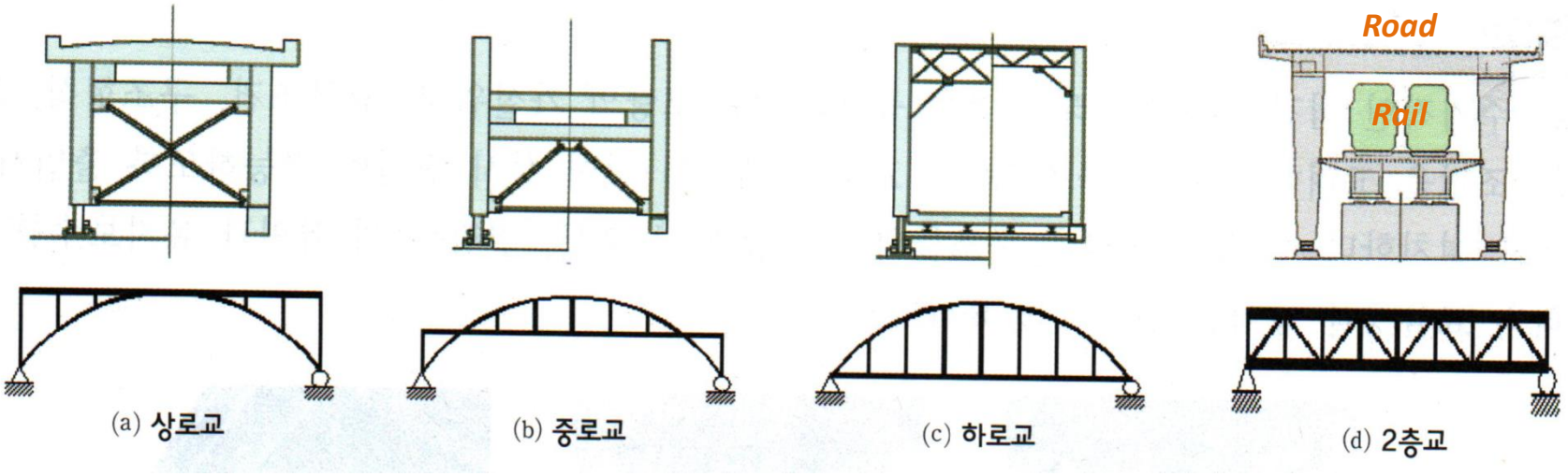




- Maintenance facility (fixed and movable)


Bridge Types

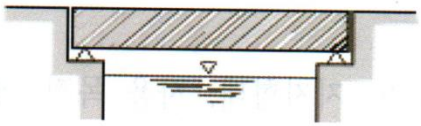
- Bridge Types Depending on Deck Positions



Deck Bridge *Half-through Bridge* *Lower Route Bridge* *Double-deck Bridge*

Bridge Types

- **Bridge Types Depending on Support Types**

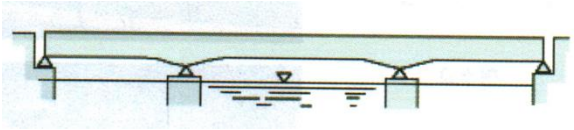


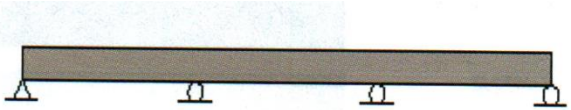
Single Span Bridge (단순교)

- Separated spans/decks

- 정정구조물로 구조해석이 쉽고 시공이 간편

- 처짐이 커서 긴 지간에 는 적용이 곤란, 차량의 주행성이 떨어짐, 소규모교량, 철도교



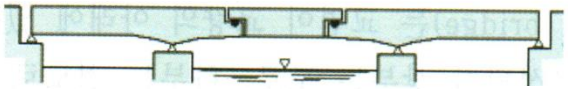


Continuous Span Bridge (연속교)

- Continuous deck

- 부정정구조물로 처짐이 작아 긴 지간에 적용

- 해석이 복잡함, n경간 연속교

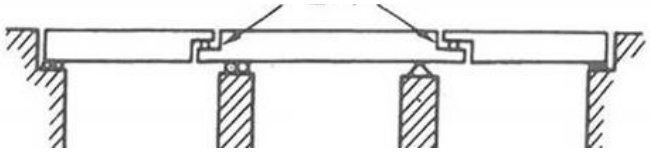


Gerber(게르버) Bridge

- Adding hinges to the continuous span bridge to convert "indeterminate" to "determinate"

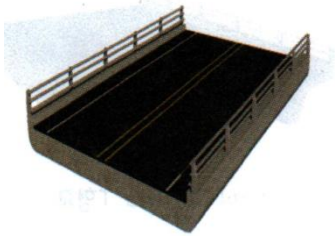
- 구조해석이 쉬우나 힌지 사이의 보가 과다하게 처지는 문제가 있음

Hinge



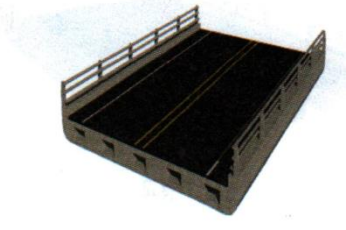
Bridge Types

- **Bridge Types Depending on Deck Types**



RC 슬래브교

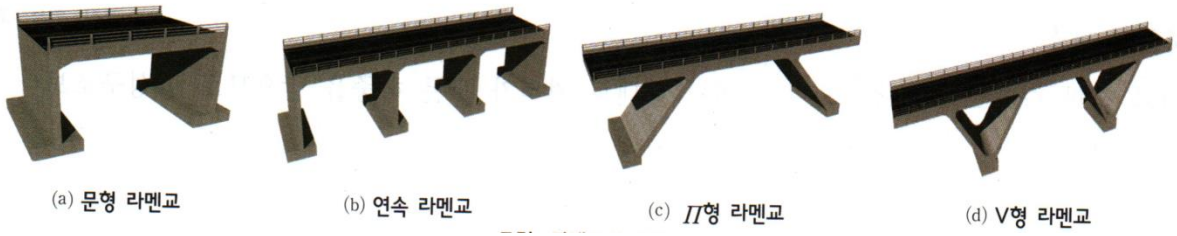
RC Slab Bridge
Should avoid long-length due to increase self-load



중공 슬래브교

Hollow Slab Bridge
Reduce self-load with holes

Slab bridge
- Slab top structure: short-length span (single span: 5-15m, continuous span: 10-30m)
- Low-height top structure (1/16-1/20 of the bridge length)



(a) 문형 라멘교 (b) 연속 라멘교 (c) Π형 라멘교 (d) V형 라멘교

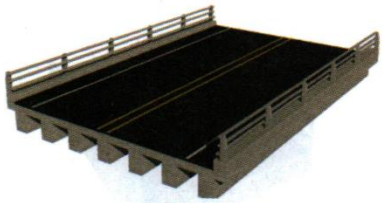
Rahmen(Rigid-Frame) Bridge
- Connected top and bottom structures
- Economical with low-pier-height and short-span bridges
- No need for expansion joints till 50m
- Spaces under the bridge for overpass road or river crossing
- Easy maintenance, good appearance

Bridge Types

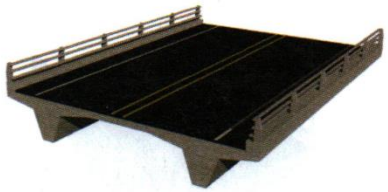
GIRDER BRIDGE

The weight of the girder pushes straight down on the piers

- **Bridge Types Depending on Deck Types: Girder Bridge**



(a) T형교



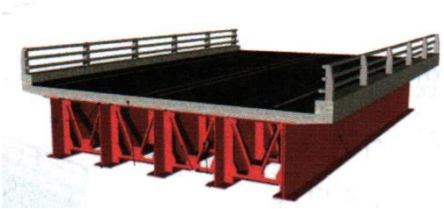
(b) Double T형교

T-Shape (T형교)

- Usually used for short spans (30m)

- Less self-load than slab bridges

- Double T-shape: 50m span with prestress, horizontal tendons due to a big gap b/w girders



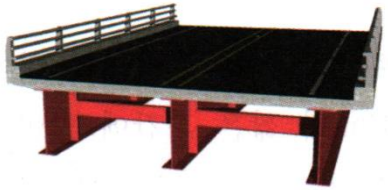
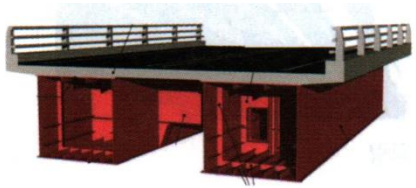


Plate Girder (강판형교)

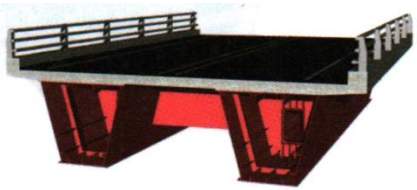
- Use I-shape steel girder (50m)

- Require many steel members, complicated

- Low horizontal strength → weak for curved roads



(a) 직사각형



(b) 제형

Plate Box Girder (강상형교)

- Widely used (50-60m)

- Good for curved and widened roads

- Steel box is prefabricated, bolted and welded in the field → fast, easy construction

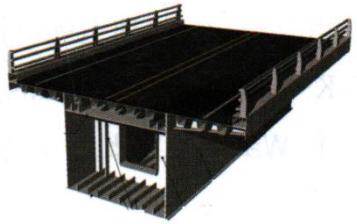
Bridge Types


진도대교 강상판


완도-신지도 연도교

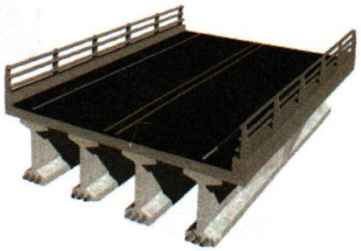

부산남항대교

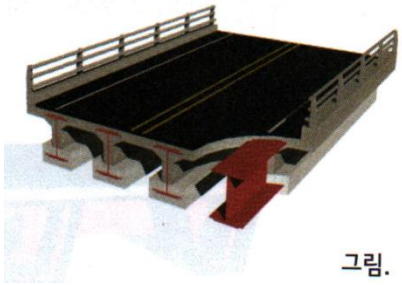
- **Bridge Types Depending on Deck Types: Girder Bridge**



Steel Plate Box Girder (강상판형교)

- Steel-plate slabs → smaller self-load → longer span (70-80m)
- Expensive due to many steel members
- Complicated field welding of the steel plate, more vibration than concrete slab





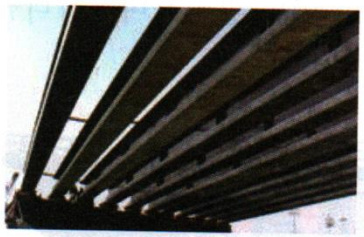


그림. 프리플렉스교량

PSC Beam

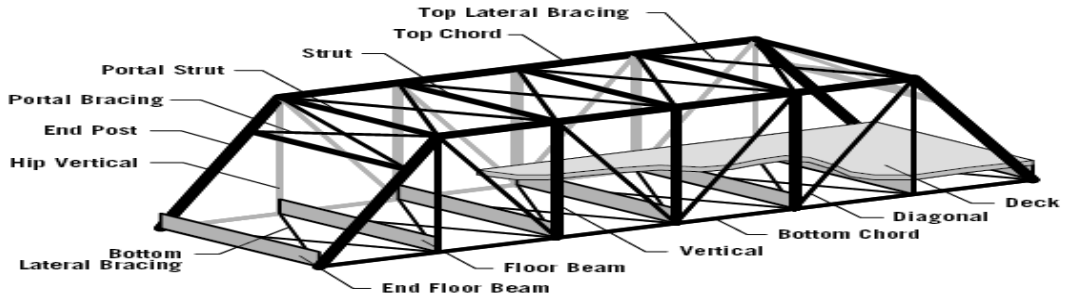
- Use pre-stressed concrete girder (20-40m)
- Cheaper construction
- 2m bottom structure for 30m span → require enough bottom spaces → For the limited spaces, use preflex bridges with I beam

Bridge Types

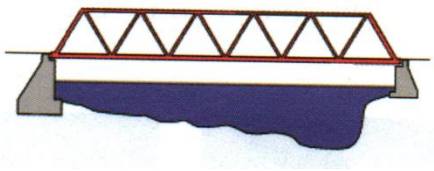
TRUSS BRIDGE

Girder bridge strengthened by trusses
Lighter than ordinary girder sections of equal length

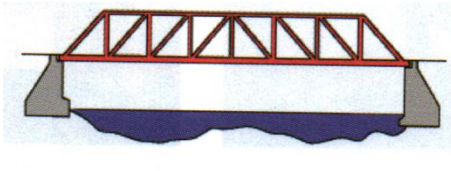
- **Bridge Types Depending on Deck Types: Truss Bridge**



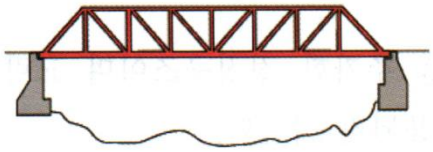
Component parts of a typical truss bridge - Isometric View [1]



Warren Truss



Howe Truss



Pratt Truss

Parker Truss

K Truss

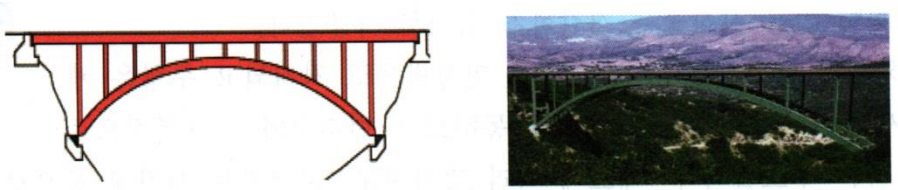
Baltimore Truss

Bridge Types

ARCH BRIDGE

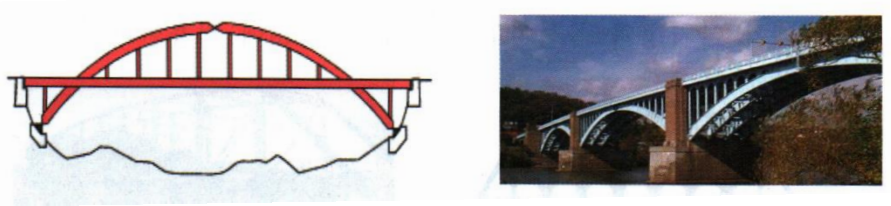
Instead of pushing straight down, the weight of an arch bridge is carried outward along the curve of the arch to the supports (abutments) at each end

- **Bridge Types Depending on Deck Types: Arch Bridge**



2-Hinged Arch

Widely used, Good appearance and economical
Applicable to sound ground conditions
Applicable to over 300m with truss braced ribs

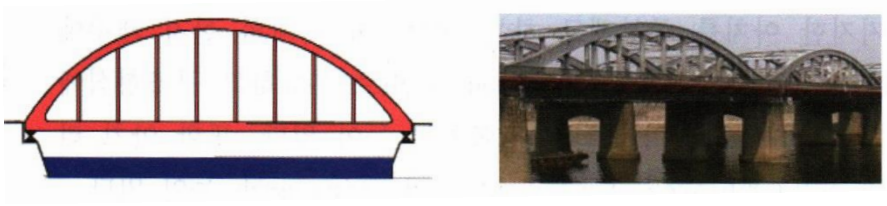


3-Hinged Arch

Possible deflection in the center hinge
Less durability, Not used that much

Fixed Arch

Most economical arch
Higher fixed moment → for sound ground conditions
Less deflection due to higher durability
Usually used for concrete bridge (difficult to apply hinges)



Tied Arch

Less horizontal loads to the tie → Applicable to poor ground conditions
Bigger loads to arch rib → Bigger rib thickness are used thus less economical

Bridge Types

- **Bridge Types Depending on Deck Types: Cable Stayed Bridge (사장교)**
  - The cables are attached to the towers, which alone bear the load
  - For long-span bridges, self-load becomes bigger thus need supports by the tower
  - In a radial pattern, cables extend from several points on the road to a single point at the top of the tower
  - In a parallel pattern, cables are attached at different heights along the tower, running parallel to one other.

Bridge Types

- **Bridge Types Depending on Deck Types: Suspension Bridge (현수교)**
  - The cables ride freely across the towers, transmitting the load to the anchorages at either end which are imbedded in either solid rock or massive concrete blocks
  - Aesthetic, light and strong, but most expensive to build

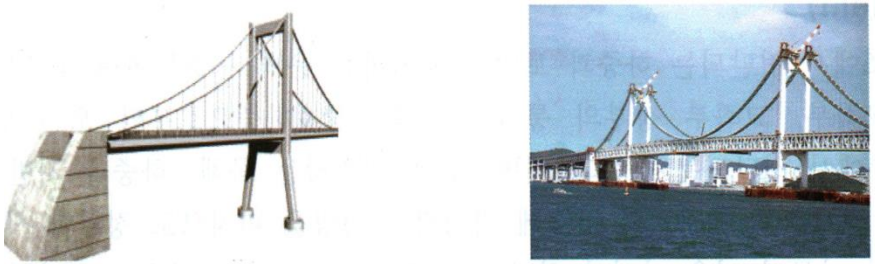


그림. 타정식 현수교(광안대교)

Earth-Anchored(타정식)
- The cables are fixed to anchorages
- No effect to stiffening girder (보강형) thus easier structural analysis and design
- Require big mass of anchorage → less attractive, more expensive with poor ground conditions

그림. 자정식 현수교(영종대교)

Self-Anchored(자정식)
- Directly fix cables into the stiffening girder
- Complicated structural analysis and design
- No need for the large anchorage

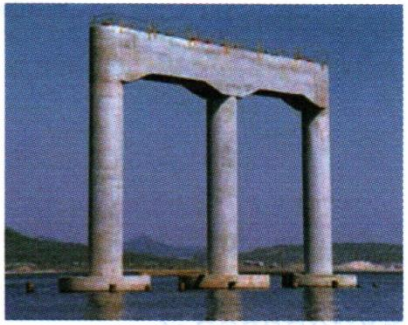
Bridge Construction

- **Bottom Structure: Pier (교각)**
  - When constructing many piers in the river, it reduces the cross section area of the river, which increases fluid velocity and scouring. To prevent flood, the cross section of pier needs to be designed as circular or oval shapes

(a) 기초 콘크리트

(b) 교각 콘크리트

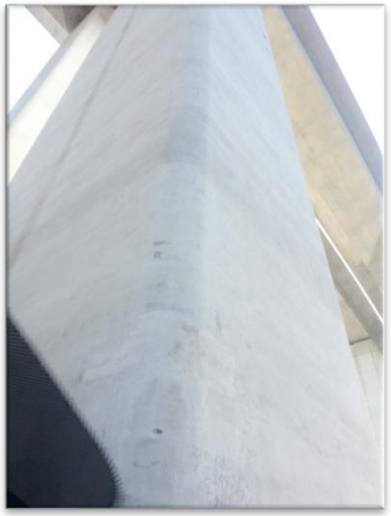
(c) 코핑부 콘크리트



(d) 교각 시공 완료

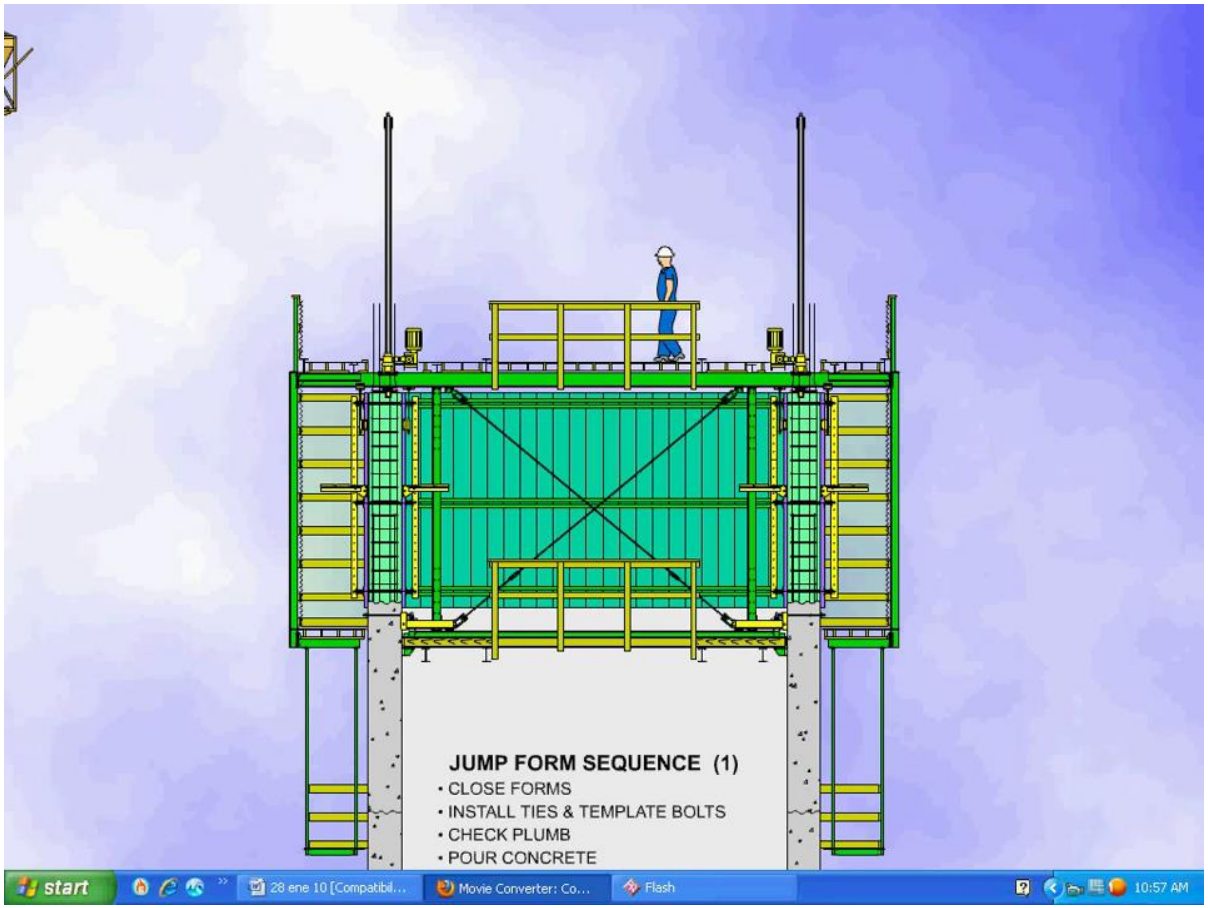
Bridge Construction

- **Bottom Structure: Pier**
  - **Sliding Form**
    - Assemble the concrete form at the bottom at the beginning and continuously lift the form to the top without form removal by using hydraulic jacks
    - Once the concrete is cured and reach the desired strength without deformation, the form moves up to the next height
    - Possible to construct 1 story each day
    - Good for chimney, cooling tower, silo, pier, bridge tower, etc.
    - No connection line, save form disposal, improve worker safety
    - No stop from the bottom to the top: 24-hour working, require accurate skills and construction methods (no cold joint), not economical for the short height



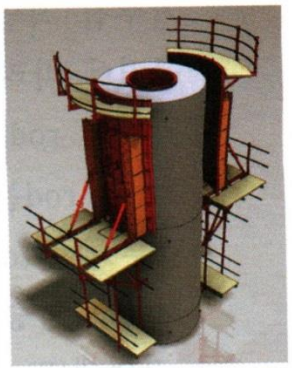
Bridge Construction

- Climbing Form



Bridge Construction

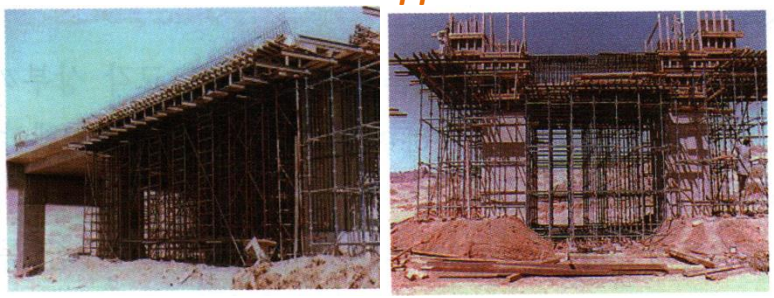
- **Bottom Structure: Pier**
  - **Climbing Form**
    - Similar concept with the sliding form, but remove forms for each story and do not use hydraulic jacks (normally use tower crane)
    - Takes longer time (5-6 days for 1 story)
    - One form unit is about 4-6m
    - Uniform placement height, more traditional method that is more familiar with workers→ good productivity
    - Equipment cost, safety risks at the high height (e.g., wind) especially for form removal operation, falling risk of workers working in gang forms



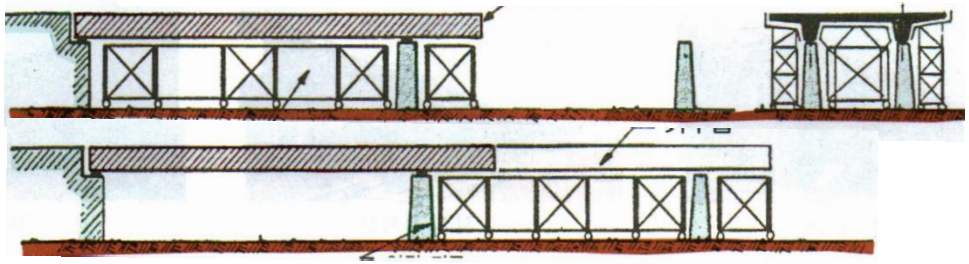
Bridge Construction

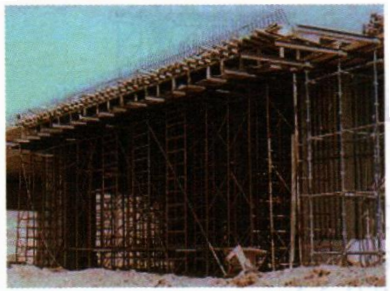
- **Top Structure: FSM (Full Staging Method, 동바리공법)**
  - For good ground strength and short height bridges
  - Install supports to the entire span to bear loading of concrete, forms, and working platform

Fixed Supports



Movable Supports





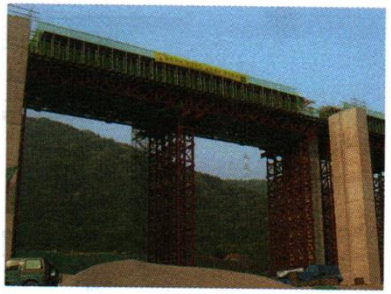
Whole Support (전체지지식)

- Flat ground and smaller than 10m height
- Simple installation and easy construction
- Steel or wood supports evenly bear the distributed loads of the top structure
- Need for no concentrated loading during concrete placement

Bridge Construction

- **Top Structure: FSM (Full Staging Method, 동바리공법)**

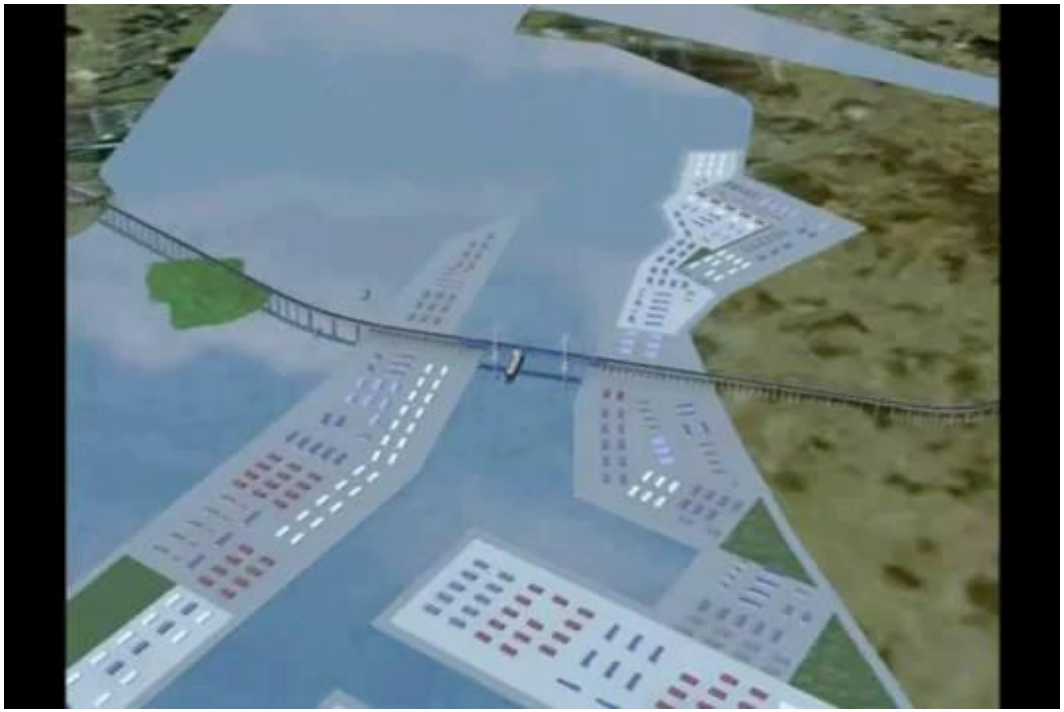
Pillar Support (지주지지식)
- Uneven ground and obstacles on the ground
- Larger than 10m height
- For poor grounds, need to drive piles



Girder Support (거더지지식)
- River having poor ground condition
- When difficult to install supports between spans
- For the cross section bridges
- When needs to use the under spaces
- For large height bridges

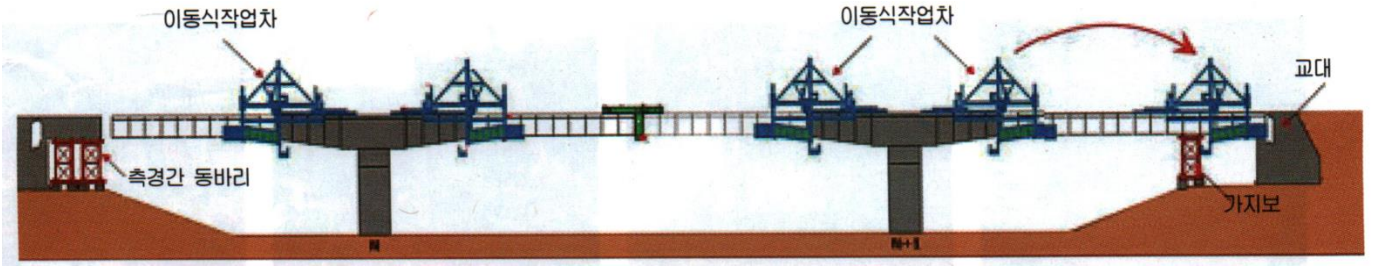
Bridge Construction

- **Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)**
  - Use form traveler or moving gantry to balance left and right-hand sides of the bridge instead of installing supports and construct 2-5m girders step-by-step
  - When support installation is difficult
  - Used for PC box girder, suspended, arch bridges

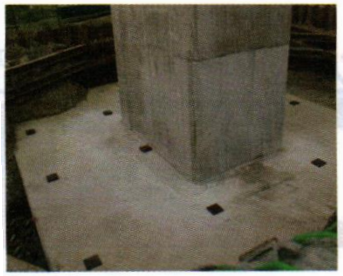


**Sheath pipe: for inserting steel strands to apply prestress*

Bridge



- **Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)**
  - **Super-capital (주두부) construction: about 90 days**


(a) Footing 상면 고르기


(b) 동바리 설치


(c) 동바리/받침보 설치


(d) 측면 거푸집 설치


(e) 측면부 철근 쉬스관 설치


(f) 내부 거푸집 설치


(g) 슬래브 철근/쉬스 설치


(h) Air Vent 설치

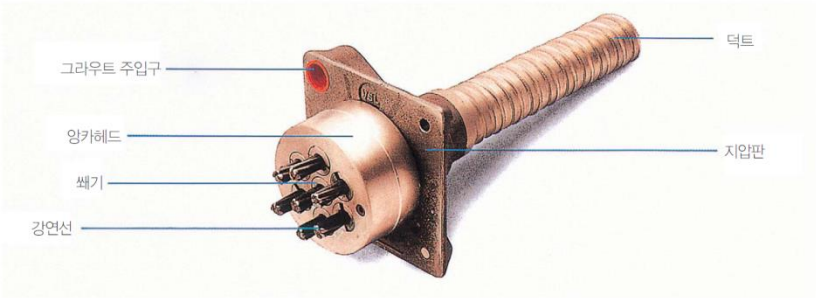

(i) 슬래브 콘크리트 타설

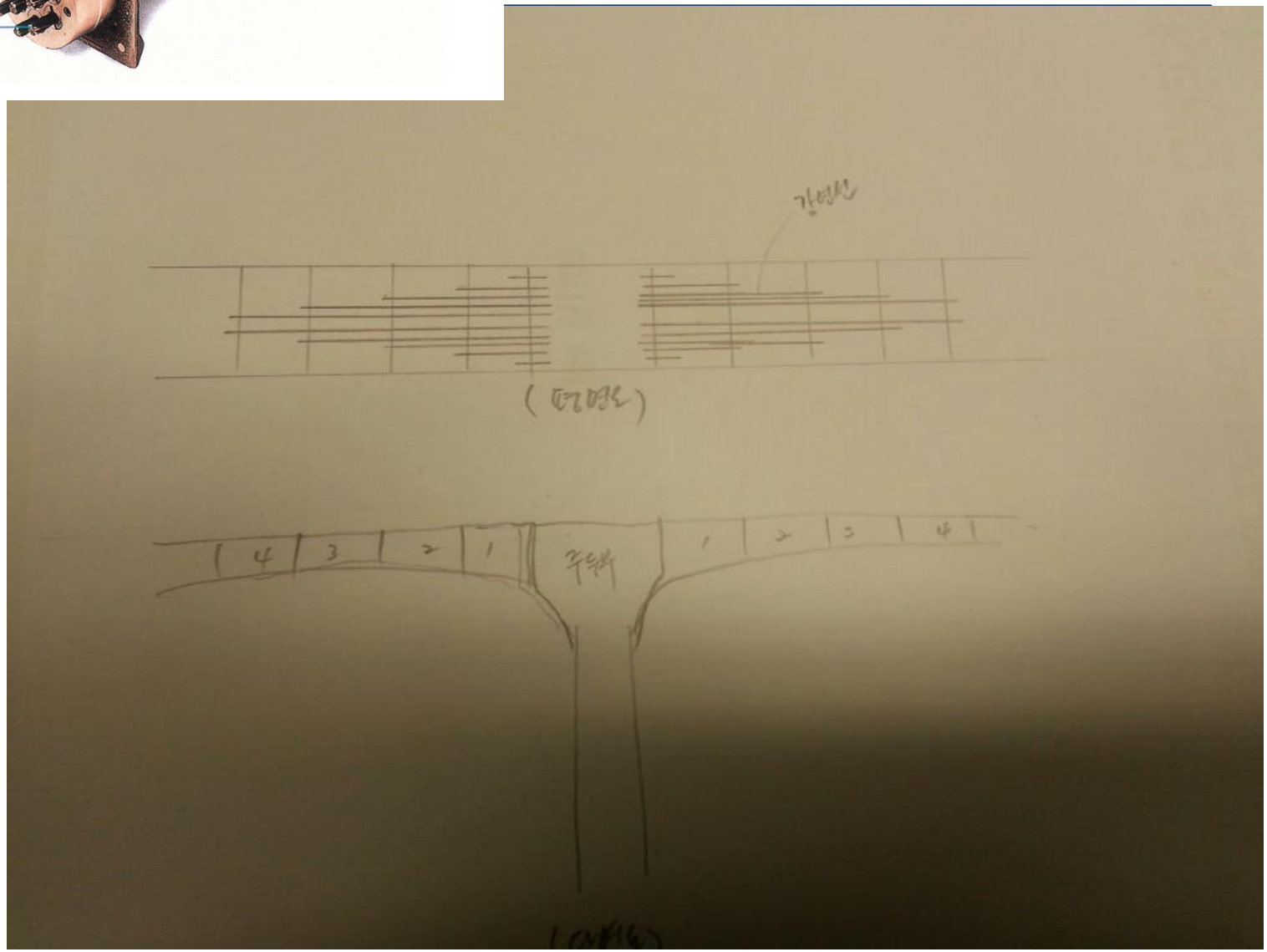

(j)(k) 인장 Jack 설치


(k) 주두부 설치


(l) 주두부 거푸집 해체

인장정착구 VSL Type EC



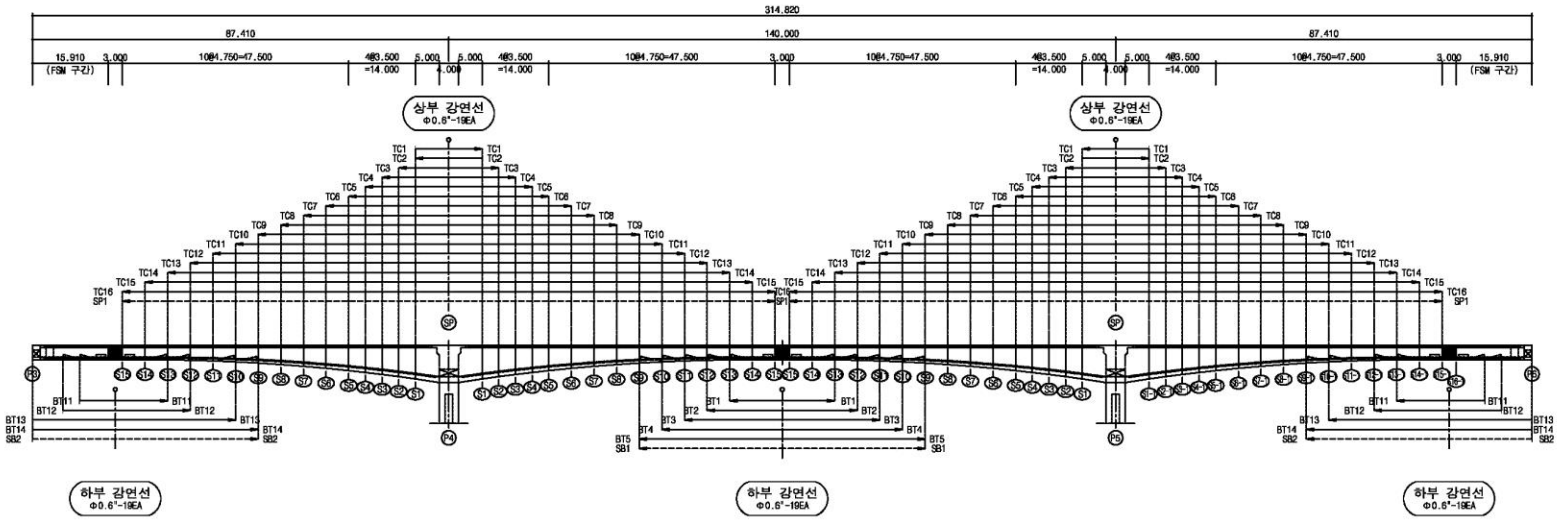


강연선 배치 개요도

배치 개요도

S=1:500

적용설계법 : 허용응력설계법, 강도설계법
설계기준강도 : 콘크리트 fck = 40 MPa
철 근 fy = 400 MPa
강 선 fpu = 1,900 MPa
설계하중 : DB-24, DL-24



[redacted]

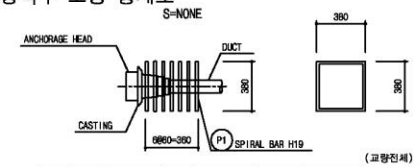
강선번호	강선길이(M)	여유긴장길이(M)	텐던개수(EA)	넥트길이(M)	총강선길이(M)	인장정착구 개수(EA)	고정정착구 개수(EA)
TC1	14.000	2	4	56.000	64.000	4	4
TC2	14.000	2	4	56.000	64.000	4	4
TC3	21.000	2	4	84.000	92.000	8	0
TC4	28.000	2	4	112.000	120.000	8	0
TC5	35.000	2	4	140.000	148.000	8	0
TC6	42.000	2	4	168.000	176.000	8	0
TC7	51.500	2	4	206.000	214.000	8	0
TC8	61.000	2	4	244.000	252.000	8	0
TC9	70.500	2	4	282.000	290.000	8	0
TC10	80.000	2	4	320.000	328.000	8	0
TC11	89.500	2	4	358.000	366.000	8	0
TC12	99.000	2	4	396.000	404.000	8	0
TC13	108.500	2	4	434.000	442.000	8	0
TC14	118.000	2	4	472.000	480.000	8	0
TC15	127.500	2	4	510.000	518.000	8	0
TC16	137.000	2	4	548.000	556.000	8	0
SP1	137.000	2	4	548.000	556.000	8	0
총 계				4934.000	5070.000	128	8

[redacted]

강선번호	강선길이(M)	여유긴장길이(M)	텐던개수(EA)	넥트길이(M)	총강선길이(M)	인장정착구 개수(EA)	고정정착구 개수(EA)
BT1	22.000	2	2	44.000	48.000	4	0
BT2	31.500	2	2	63.000	67.000	4	0
BT3	41.000	2	2	82.000	86.000	4	0
BT4	50.500	2	2	101.000	105.000	4	0
BT5	60.000	2	2	120.000	124.000	4	0
SB1	60.000	2	2	120.000	124.000	4	0
BT11	18.500	2	4	74.000	80.000	4	4
BT12	26.750	2	4	107.000	113.000	4	4
BT13	42.750	2	4	171.000	177.000	4	4
BT14	47.500	2	4	190.000	198.000	4	4
SB2	47.500	2	4	190.000	196.000	4	4
총계				1282.000	1316.000	44	20

정착구 보강 상세도

S=NONE



(교량진체)

번호	직경	길이(M)	갯수	총길이(M)	단위중량	총중량(TONF)	비고
P1	H19	10.640	200	2128.000			ADD 3%
소 계				2128.000	2.250	4.788	
총 계						4.788	4.931

[redacted]

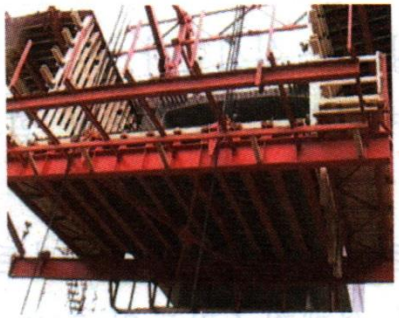
1. 강연선의 종류는 KSD 7002 SWPC7B 0.6"(Φ15.2MM)이며 저릴렉세이션 강재를 사용한다.
2. 프리스트레이싱의 즉시 손실량 산출시 적용계수는 다음과 같다.
   상부 : 곡률마찰계수:0.20/rad 파상마찰계수:0.0020/m, SLIP량:6MM
   하부 : 곡률마찰계수:0.25/rad 파상마찰계수:0.0050/m, SLIP량:6MM
3. 콘크리트의 설계기준 강도는 40MPa이며, 콘크리트의 초기압축 강도가 28MPa 이상일때 긴장작업을 시작하도록 하며, 그 이하의 경우에는 구조계산을 실시하고 이상이 없음을 증명하여 감독원의 승인을 득한후 시행한다.
4. 정착구 표시기호
   인장 정착구 ■ 일단 긴장 AIR VENT
   ■ 고정 정착구 ■ 양단 긴장 여유 긴장구
   도입 긴장력 : 주두부 — 상부: $f = 0.75\ f_{pu} = 1,425$ MPa 주두부 외 상부: $f = 0.72\ f_{pu} = 1,368$ MPa
   하부: $f = 0.72\ f_{pu} = 1,368$ MPa
5. 강연선 길이 산출시 일단긴장 및 양단긴장은 여유길이를 2.0M로 적용

인천광역시 옹진군	사 업 명	덕적~소야간 연도교 건설공사 기본 및 실시설계	△					위치정보		도 면 명	강연선 배치 개요도
	시설/공구		△					축 척	S=1:NONE		
(주)평화엔지니어링 (주)서영엔지니어링 극동엔지니어링(주)	건설분야	토목	건설단계	실시설계	△ 개정번호	2014.07 날짜	개 정 내 용	조충영 과업책임자	김홍식 분야별책임자	양병홍 설계자	도면번호		편철번호	8.035

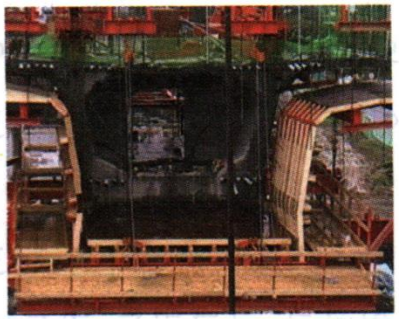
Bridge Construction

- **Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)**
  - Segment Construction (Form Traveler Installation)

(a) F/T 조립-1



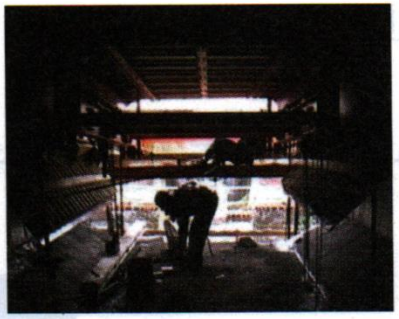
(b) F/T 조립-2



(c) F/T 조립-3

(d) 외측 거푸집 설치

(e) 외측 거푸집 설치



(f) 내부 거푸집 설치

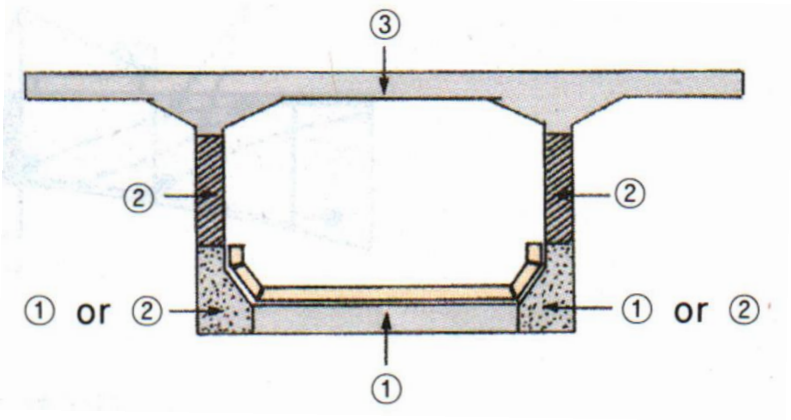
(g) F/T 조립 완료

(h)Main rail 고정

Design: 1 month, Manufacturing: 3 months, Installation: 1 months

Bridge Construction

- **Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)**
  - **Segment Construction (Form Traveler)**
    - Normal segment span: 3-5m
    - Concrete placement: low fringe through the opening of the bottom plate → Connection b/w the low fringe and the body → Body → Cantilever → Top plate → Connection b/w the top plate and the body
    - Key segment: connection b/w segments



Segment Construction: *form setting (2 days), rebar and formwork (3 days), concrete placement (1 day), Curing and tensioning (4 days), Form Traveler detachment (2 days)*

Side Span Structure (측경간단부): *20 days for 7m*

Key Segment: *20 days*

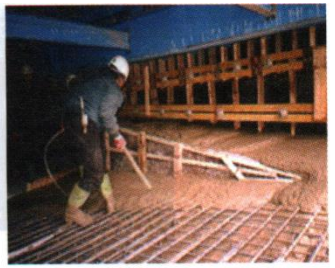
Bridge Construction

- **Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)**
  - **Segment Construction (Form Traveler)**


① 이동식 거푸집 설치

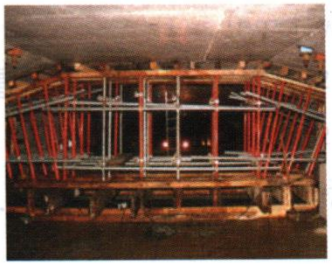

② 이동식 거푸집 조립


③ 세그먼트 철근 조립


④ 콘크리트 타설

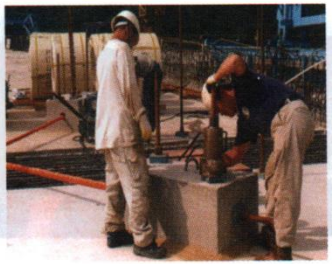

⑤ 세그먼트 인장


⑥ 세그먼트 그라우팅


⑦ 강연선/lifting collar 설치


⑧ 키 세그먼트 수평버팀 설치


⑨ 키 세그먼트 철근 조립


⑩ 키 세그먼트 강봉 인장


⑪ 키 세그먼트 콘크리트 타설


⑫ 키 세그먼트 연결

Bridge Construction

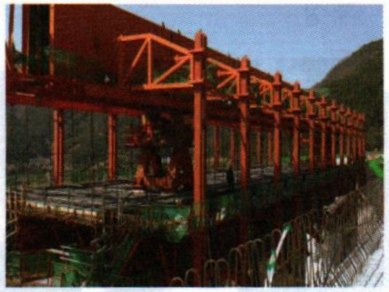
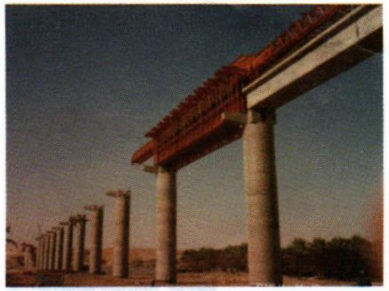
- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**

Bridge Construction

- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**

Bridge Construction

- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**
  - Install forms on the movable scaffolding structure and place concrete
  - **Above type**: hang forms to the above scaffolding structure

  - **Below type**: structure supports forms


Bridge Construction

- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**
  - Advantages
    - Fast, safe, and productive construction
    - Less labor input and construction under rainy weather if roof is installed
    - Reusable forms and scaffolds
  - Disadvantages
    - Expensive manufacturing of the system
    - Difficult applicable to curved and changeable cross sections

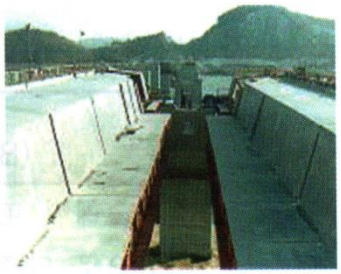
Bridge Construction

- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**


① 교각 브래킷 설치

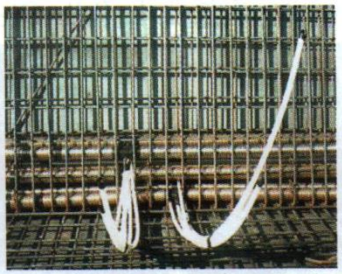

② 가벤트 설치


③박스 거더/세로 빔 설치


④ MSS 거푸집 설치


⑤ 하부 철근 조립


⑥ 내부 거푸집 조립


⑦ 하부 VENT 호스 설치


⑧ 상부 철근 조립


⑨ 상부 콘크리트 타설

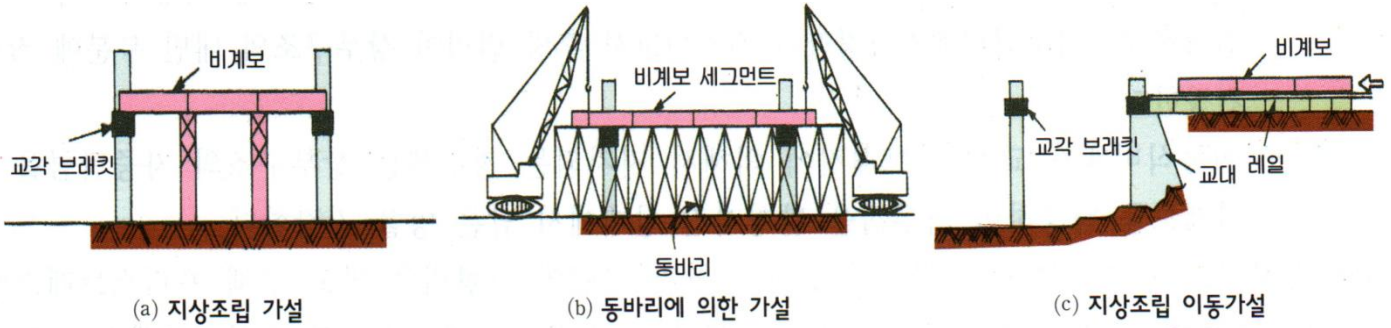

⑩ 강선인장


⑪ 그라우팅 작업


⑫ MSS launching

Bridge Construction

- **Top Structure: MSS (Movable Scaffolding System, 이동식 비계공법)**



  - Place concrete while checking the left-right balance to prevent twisting

  - **For 1 span**: Concrete placement (1 day) → Concrete curing (3 days) → Tensioning and detaching MSS (1 day) → Moving MSS (1 day) → Outer form placement (2 days) → Strand, rebar, inner form placement (5 days)
  - System design and manufacturing (3 months), installation at field (1.5 month)