*Week 12*

# Bridge

**457.308 Construction Methods and Equipment**

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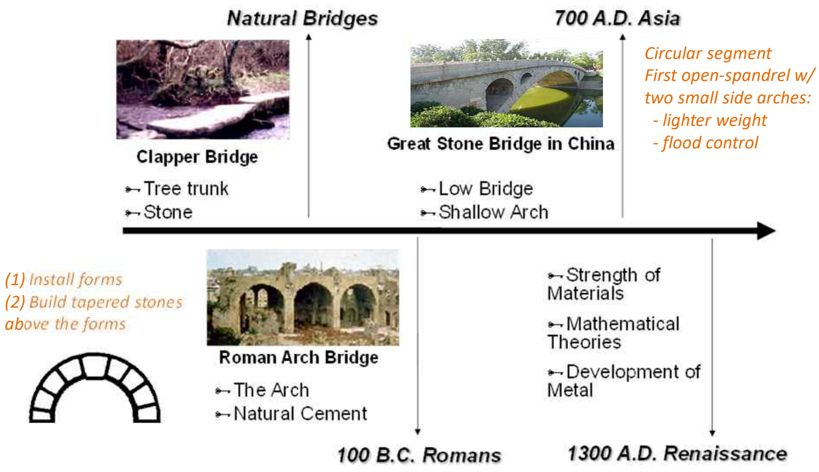
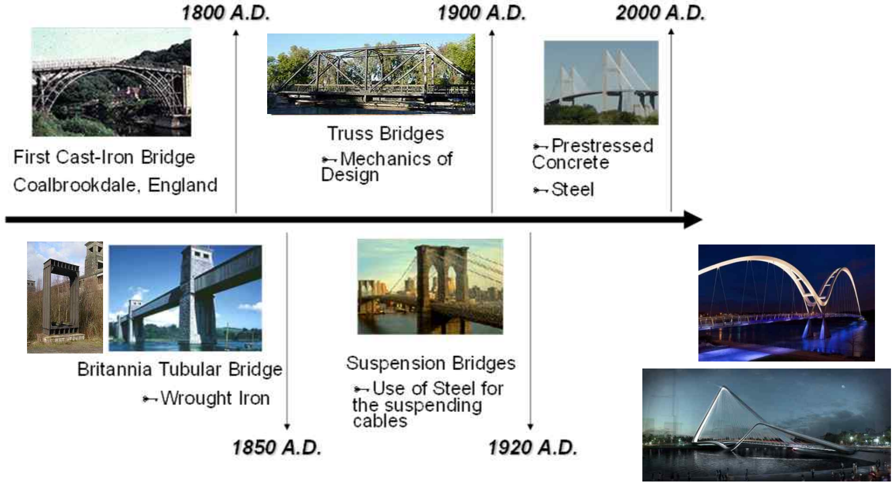
# History of Bridge Development



# History of Bridge Development

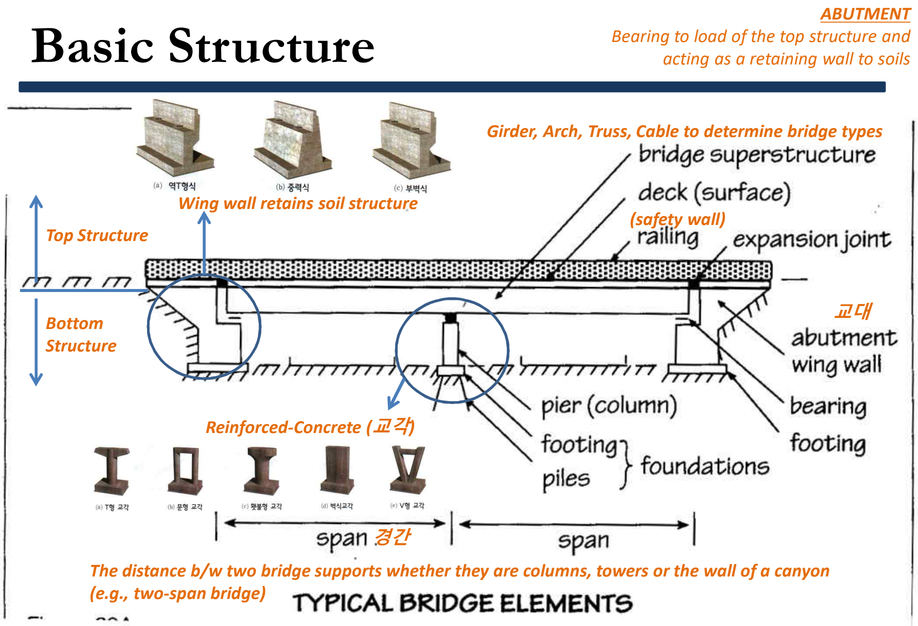



# Bahrain's North Manama Causeway

# 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."*

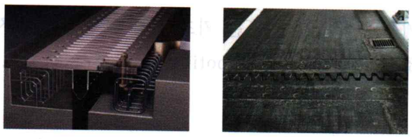
# Basic Structure



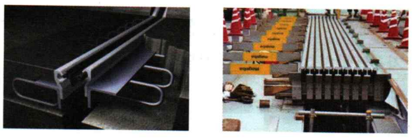
# Basic Structure

- **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)



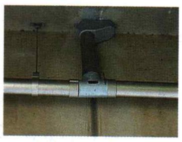
(a) finger type



(b) rail type

# Basic Structure

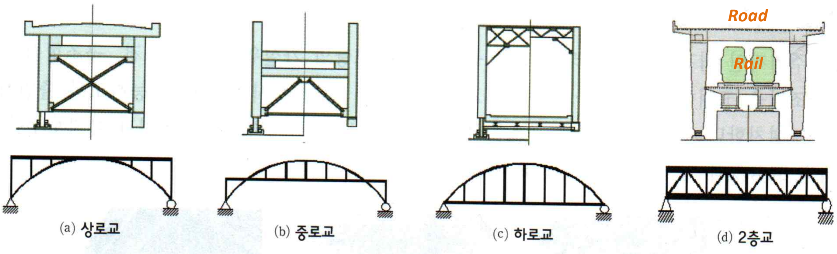
- **Drainage facility**



- **Maintenance facility (fixed and movable)**

# Bridge Types

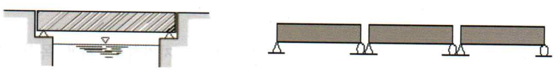
- Bridge Types Depending on Deck Positions




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

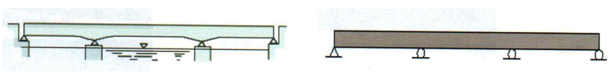
# Bridge Types

- Bridge Types Depending on Support Types



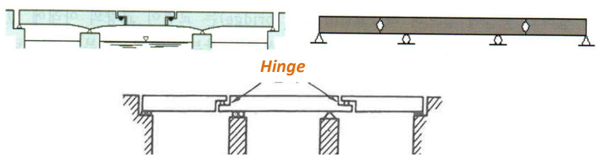
***Single Span Bridge (단순교)***

*- 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*

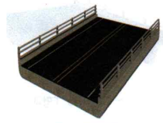



***Gerber(게르버) Bridge***

*- Adding hinges to the continuous span bridge to convert "indeterminate" to "determinate"*
*- 구조해석이 쉬우나 힌지 사이의 보가 과다하게 처지는 문제가 있음*

# 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)*

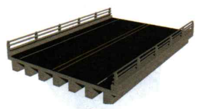
(a) 문형 라멘교 (b) 연속 라멘교 (c) Π형 라멘교 (d) V형 라멘교

***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

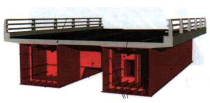


(a) T형교

(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*

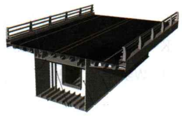
# Bridge Types

진도대교 강상판

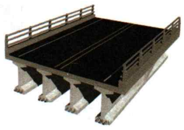
완도-신지도 연도교

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*



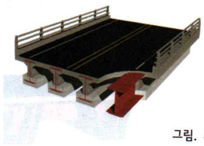


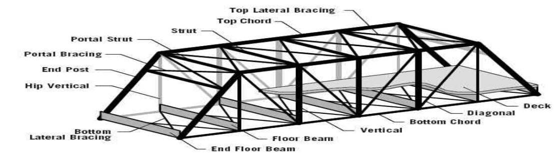
그림. 프리플렉스교량

***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*

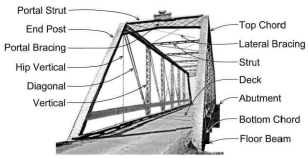
# Bridge Types

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

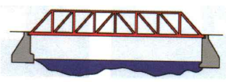
- **Bridge Types Depending on Deck Types: Truss Bridge**



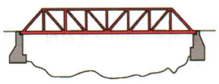

Component parts of a typical truss bridge - Isometric View




*Warren Truss*



*Howe Truss*



*Pratt Truss*

*Parker Truss*

*K Truss*

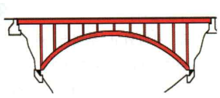
*Baltimore Truss*

# Bridge Types

***ARCH BRIDGE***

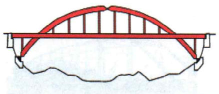
*Instead of pushing straight down, the weight of an arch bridge is carried outward along the curve of the arch to the supports (abutments) at each end*

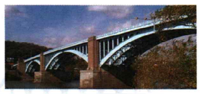
- **Bridge Types Depending on Deck Types: Arch Bridge**



***2-Hinged Arch***

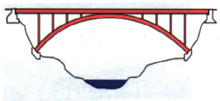
*Widely used, Good appearance and economical*
*Applicable to sound ground conditions*
*Applicable to over 300m with truss braced ribs*





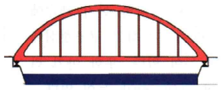
***3-Hinged Arch***

*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

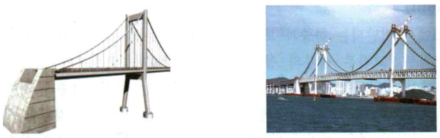


그림. 타정식 현수교(광안대교)

*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

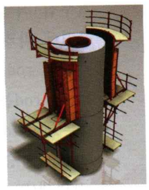
- **Bottom Structure: Pier**
  - **Sliding Form**
    - Assemble the concrete form at the bottom at the beginning and continuously lift the form to the top without form removal by using hydraulic jacks
    - Once the concrete is cured and reach the desired strength without deformation, the form moves 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

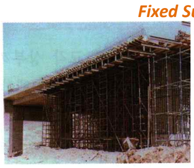
- **Bottom Structure: Pier**
  - **Climbing Form**
    - Similar concept with the sliding form, but remove forms for each story and do not use hydraulic jacks (normally use tower crane)
    - Takes longer time (5-6 days for 1 story)
    - One form unit is about 4-6m
    - Uniform placement height, more 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

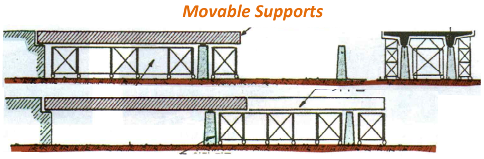
# Bridge Construction

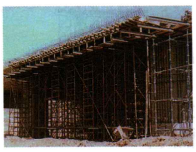
- **Top Structure: FSM (Full Staging Method, 동바리공법)**
  - For good ground strength and short height bridges
  - Install supports to the entire span to bear loading of concrete, forms, and working platform

*Fixed Supports*




*Movable Supports*



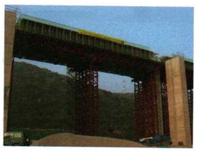


***Whole Support (전체지지식)***
*- Flat ground and smaller than 10m height*
*- Simple installation and easy construction*
*- Steel or wood supports evenly bear the distributed loads of the top structure*
*- Need for no concentrated loading during concrete placement*

# 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*



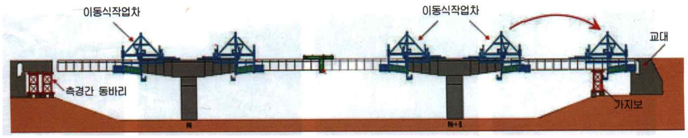
*__Girder Support (거더지지식)__*
*- River having poor ground condition*
*- When difficult to install supports between spans*
*- For the cross section bridges*
*- When needs to use the under spaces*
*- For large height bridges*

# 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

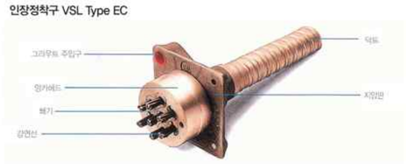
*Sheath pipe: for inserting steel strands to apply prestress*

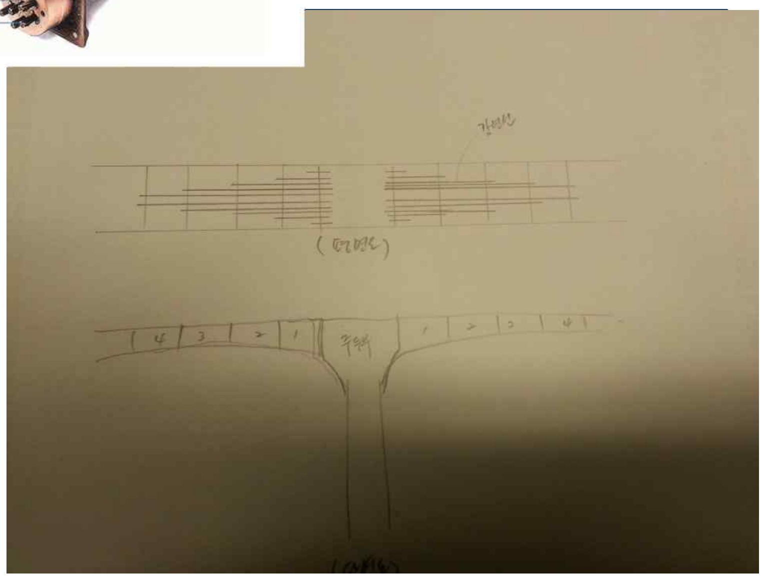
# Bridge

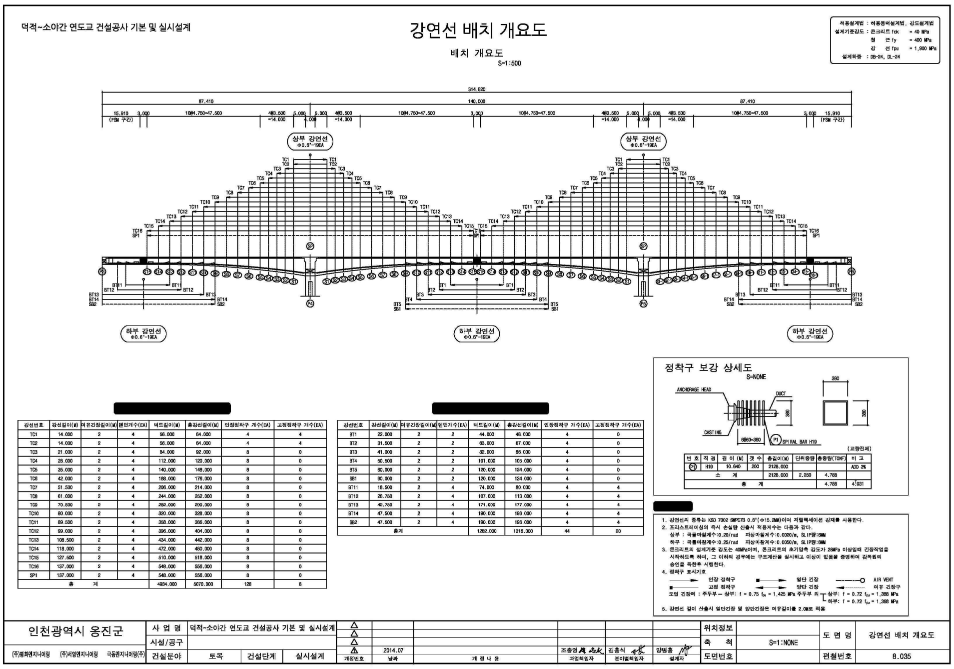



- Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)
  - Super-capital (주두부) construction: about 90 days


인장정착구 VSL Type EC

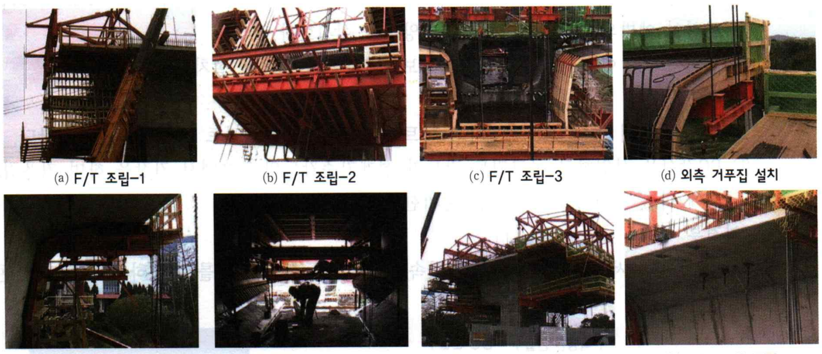





# Bridge Construction

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



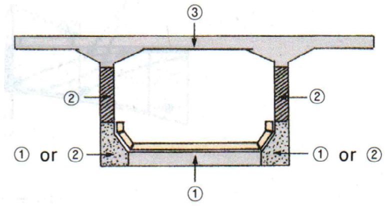
(a) F/T 조립-1 (b) F/T 조립-2 (c) F/T 조립-3 (d) 외측 거푸집 설치

(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

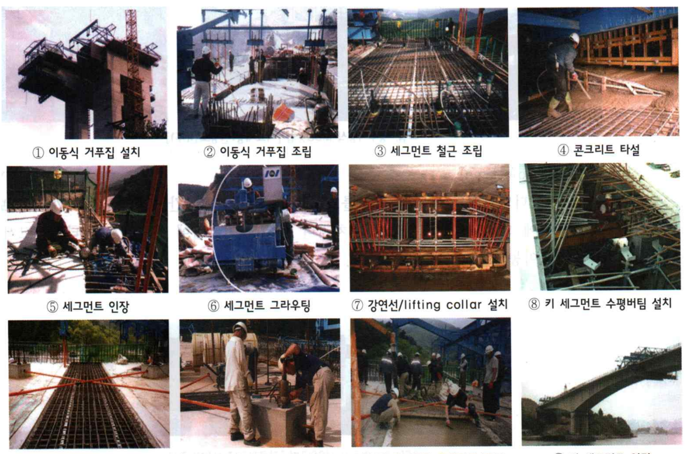
- Top Structure: FCM (Free Cantilever Method, 캔틸레버공법)
  - Segment Construction (Form Traveler)
    - Normal segment span: 3-5m
    - Concrete placement: low fringe through the opening of the bottom plate → Connection b/w the low fringe and the body → Body → Cantilever → Top plate → Connection b/w the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



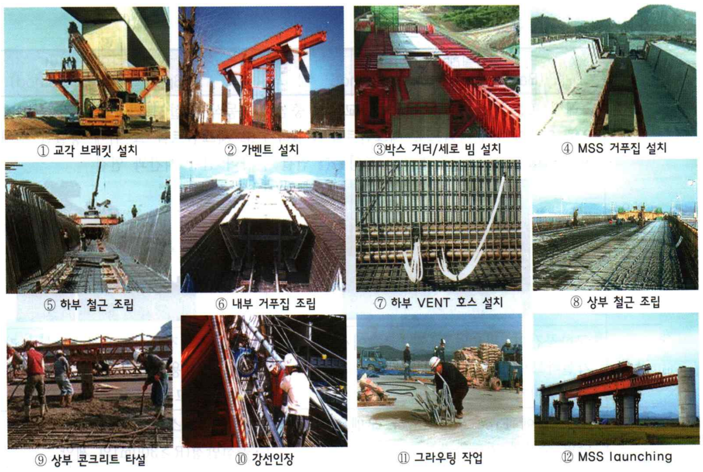
  - **Below type**: structure supports forms


# 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

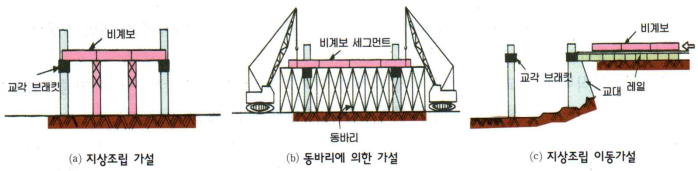
# Bridge Construction

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




# Bridge Construction

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




  - Place concrete while checking the left-right balance to prevent twisting
  - **<u>For 1 span</u>**: 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)

# Bridge Construction

- Top Structure: PSM (Precast Segment Method)
  - Structurally same as FCM but use precast segments and connect them based on post tension → faster construction
  - Additional cost for segment manufacturing sites and storage


# Bridge Construction

- Top Structure: PSM (Precast Segment Method)
  - Segment Manufacturing

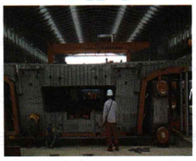

① 제작장 설치


② 거푸집 거치


③ 철근조립

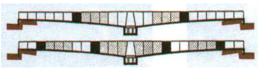

④ 콘크리트 타설


⑤ 양생

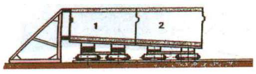

⑥ 거푸집 해체

# Bridge Construction

- Top Structure: PSM (Precast Segment Method)
  - Segment Manufacturing
    - Select manufacturing and storage sites as close as to the construction field
    - Do foundation construction for the manufacturing site as well to prevent segment deformation due to settlement
    - Manufacturing site: material storage, strand manufacturing site, segment manufacturing site, concrete batch plant, segment storage for 28 days, curing/water/electricity supply, office, etc.
    - 1 pier segment per 3 days, 2 normal segments per 2.5-3 days



***Long Line Method***
*- Set up the entire top structure on to the manufacturing facility and manufacture segments while moving one or several forms*
*- Advantages for changeable bridge cross sections*
*- Require large spaces*
*- Easy and accurate manufacturing, Direct curing at the same location*




***Short Line Method***
*- Manufacture segments one by one*
*- Advantages for uniform cross sections*
*- Need for moving to storage yards, Difficult manufacturing*

# Bridge Construction

- Top Structure: PSM (Precast Segment Method)

# Bridge Construction

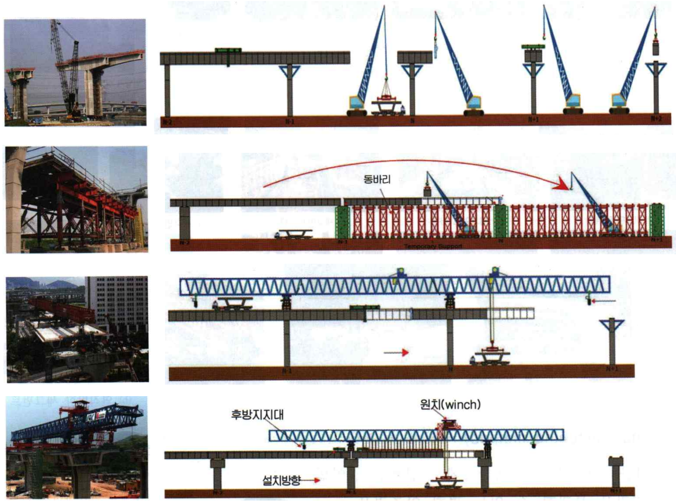
- **PSM (Precast Segment Method) – 캔틸레버 가설법**

*Crane*

*Crane + Supports*

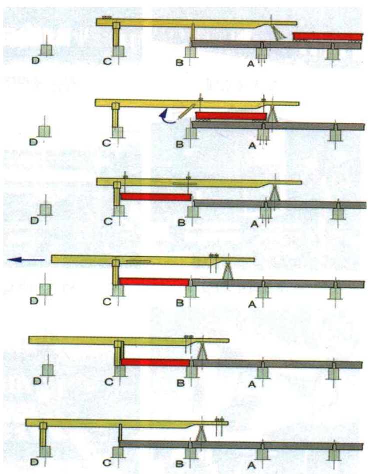
*Movable Hoist (끌어 올리기만)*

*Movable Working Girder (매달아서 운반/가설)*




# Bridge Construction

- **PSM (Precast Segment Method) – 경간단위 가설법**



*Open back supports and move precast span segment*

*Close back supports and open center supports*

*Move the span segment to the installation position*

*Push launching gantry by the back supports*

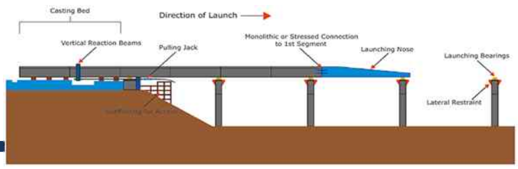
*Stop pushing and install center supports to the next spot*

*Install front supports to the next spot*

# Bridge Construction

- Top Structure: PSM (Precast Segment Method)
  - **Construction Risks**
    - Careful mixing of epoxy and hardening agents (에폭시 수지와 경화제 혼합) is required for connecting adhesiveness control
    - Careful deflection control of cantilevers
      - Caused by (1) manufacturing errors, (2) construction errors, (3) design errors especially (as-planned vs as-built)
      - Keep 6mm or less positioning error rates with adjacent segments
      - Keep 0.3% or less vertical installation degree comparing with the design

# Bridge

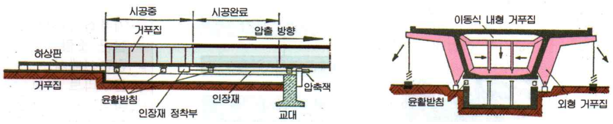



- Top Structure: ILM (Incremental Launching Method, 연속 압출공법)

# Bridge Construction

- Top Structure: ILM (Incremental Launching Method)

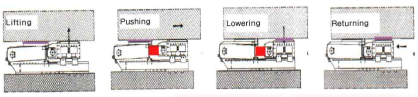
(a) 기초 콘크리트 타설
(b) 제작장 철근 조립
(c) 제작장 거푸집 설치
(d) 제작장 기초
(e) 강선 제작장
(f) 제작장 mould 덮개
(g) 제작장 전경
(h) Bottom jack설치




# Bridge Construction

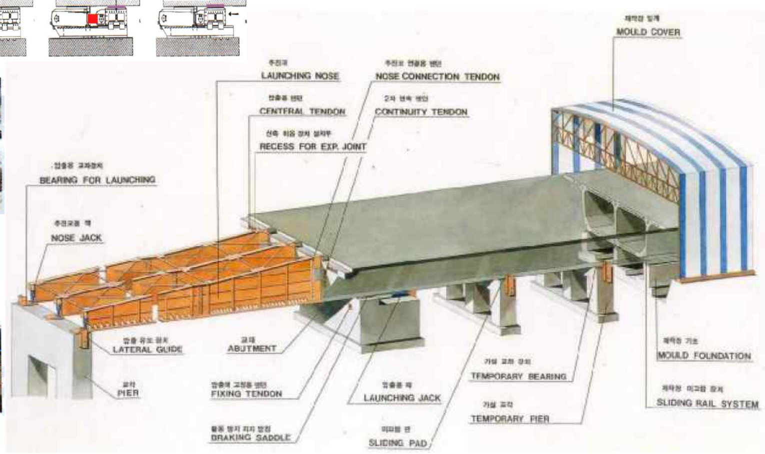
Breaking Saddle

- Top Structure: ILM (Incremental Launching Method)




Launching Jack

Nose Jack



# Bridge Construction

- **Top Structure: ILM (Incremental Launching Method)**
  - **Advantages**
    - Easy project and quality control and safe
    - Repeated and fast, easy material management
    - No weather effects
    - Continuous deck for better riding quality
  - **Disadvantages**
    - Need spaces for manufacturing facilities
    - Applicable for straight or R > 450m bridges: difficult for changeable cross sections and bridge heights
    - Applicable for 60m span even considering launching nose and temporary pier
    - Expansive first investment cost

# Bridge Construction

- **Top Structure: PSC Beam**

# Bridge Construction

- Top Structure: PSC Beam Manufacturing


(a) 제작대 설치

Careful for Differential Settlement


(b) 철근, 쉬스 조립

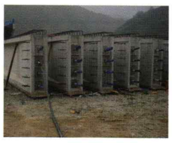
Strong Enough to Bear Concrete Forces, Carefully Locate Post Tensioning Anchorage

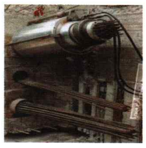

(c) 거푸집 조립


(d) 콘크리트 타설


(e) 양생

Steam after 3-4 hours from the placement


(f) 거푸집 해체


***Post Tensioning***

*Tensioning from both sides but better to use 1 hydraulic jack for uniform force*

# Bridge Construction

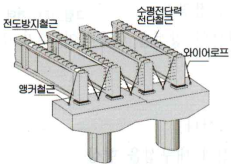
- Top Structure: PSC Beam Placement


(a) PSC Beam 운반

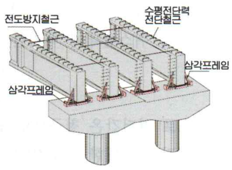

(b) PSC Beam 거치


(c) Cross beam 설치

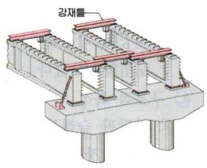

(b) 슬래브 콘크리트 타설



(a) 와이어로프 설치



(b) 삼각 프레임 설치



(c) 강재틀 설치

***Fixing Beam to Pier & Bolting to Shoe & Immediate Cross Beam Installation***

# Bridge Construction

- Top Structure: PSC Beam
  - IPC (Incremental Prestressed Concrete) Girder
    - 일반적으로 PSC 빔은 1회에 긴장력을 도입하여 모든 설계 하중을 받으므로 초기에 모든 설계하중과 긴장력을 받는 큰 단면과 형고가 필요하여 거더 자중이 증가하므로 장경간에 불리
    - IPC 거더는 단계적으로 긴장력을 도입(1차: 제작 시, 2차: 시공 후)하므로 거더 자중이 작아서 장경간 시공이 가능하며 2차 긴장력 도입으로 연속 지점부에 대한 구조적 안전성과 내구성을 향상


(d) 거푸집 제거/양생


(e) 1차강선 인장/그라우팅


(f) 빔 운반/거치

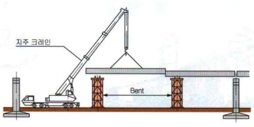

(g) 슬래브 Conc' 타설


(h) 2차강선 인장

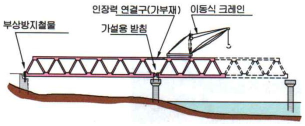

(i) IPC 교량 시공 완료

# Bridge Construction

- Steel Bridges



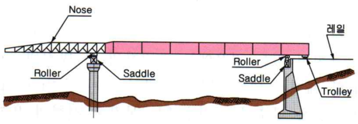

***Bent Method***
- *Use crane to connect the bridge structures with temporary supports by bents*
- *Simple and economical*
- *Construction in a load-free condition, good for curved bridge*
- *Fast construction, not economical for high height*
- *Need spaces for crane operation, need for stable ground*
- *Careful and step-by-step removal of bents considering structural conditions of the entire bridge span*



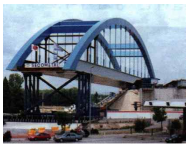
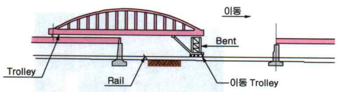

***Cantilever Method***
- *Good in valley, river, sea requiring high height and frequent spans (difficult for bent installation)*
- *Continuously connect plate box girder*
- *Possible one-way or two-way construction (need to keep balancing)*
- *Very difficult adjustment after placement*

# Bridge Construction

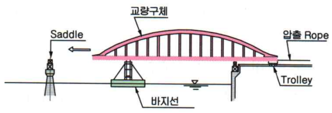
- **Steel Bridges: Incremental Launching (압출가설공법)**


*Launching Nose*


*Movable Bent Trolley*
*Require rail*

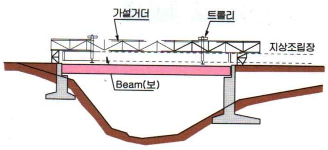




*Barge*
*No rail requirement*
*Use guide rope for alignment*

# Bridge Construction

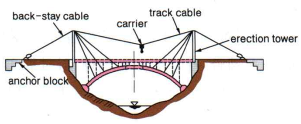
- **Steel Bridges**

*수직 매달기식*
*Main rope를 가설용 철탑에 걸쳐 놓고서 직접 빔을 매달아서 조립(아치교, 트러스교 등에 적합)*




*Temporary Girder Method (가설거더공법)*
*보조 거더를 사용하여 가설하는 방법, 지간이 길면 가설비가 크고 가설거더의 처짐 발생 위험*

*경사 매달기식*


*케이블식 가설공법*
- *Advantages to river, valley, sea*
- *Expansive, long preparation time*
- *Separate towers for bearing and cranes*

*Pontoon Method (일괄가설공법)*
*Manufacture whole structure → Transportation → Installation*


(a) Floating crane 예항


(b) 대선 예항

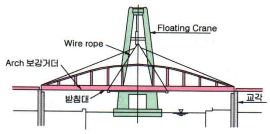

(c)트레일러 이용 방법

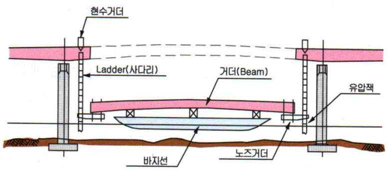
# Bridge Construction

- Steel Bridges: Pontoon Method (일괄가설공법)

***Floating Crane (Cranes set up on the barge)***
*Deliver the bridge span using the float crane*

(a) 지상조립 (b) 예항 (c) 가설, 거치



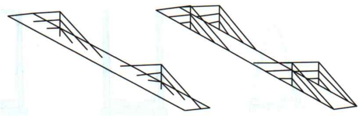

***Lift-up Barge***
*Set up lifting systems on the barge bents*

# Bridge Construction

- Cable Stayed Bridge (사장교)

# Bridge Construction

- **Cable Stayed Bridge**
  - 주탑 위의 교각 상단에 설치한 케이블로 주형을 매단 구조물이며 케이블 장력을 조절하여서 각 구조부재의 단면력을 균등하게 분배하여 휨모멘트를 현저하게 감소시키므로 경간이 긴 교량을 경제적으로 설계할 수 있음



(a) 1면 케이블 (b) 2면 케이블

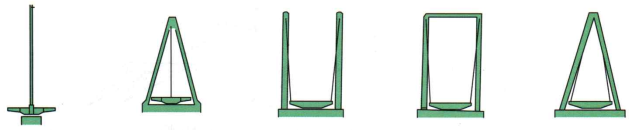
***Single Cable***

*- Better appearance, narrow width, good view opening*
*- Need a median strip*
*- Need protection for twisting forces*

***Double Cable***

*- Wide width, Better for twisting forces → long span*

(a) 방사형식 (b) 팬형식 (c) 하프형식



(a) 1본주 형식 (b) A형 형식 (a) 2본주 형식 (b) 문형형식 (c) A형 형식

(1) 1면 케이블 형상 (2) 2면 케이블 형상

# Bridge Construction

- **Cable Stayed Bridge**

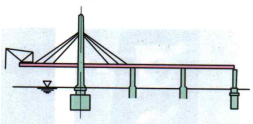


그림. 캔틸레버 공법

***Girder***

*Better stability*
*Easier construction*

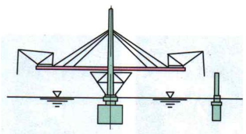


그림. 밸런스드(균형) 캔틸레버 공법

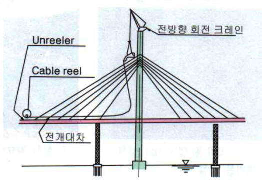



그림. 탑 크레인에 의한 방법

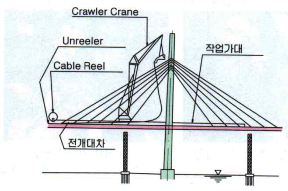
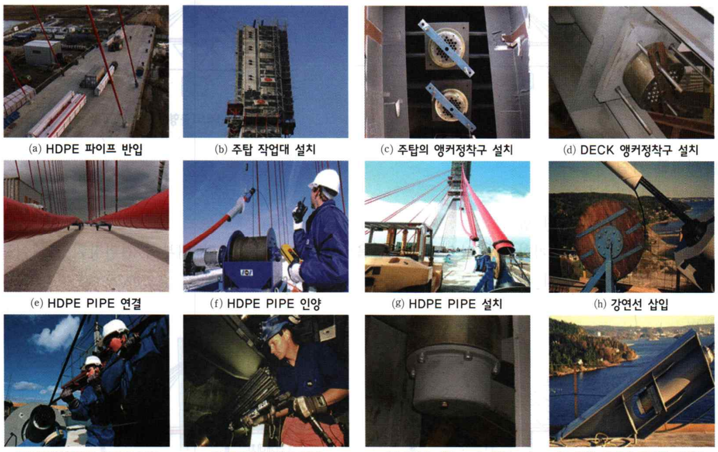



그림. 교상 크레인에 의한 방법

***Other: catwalk + winch*** *(will be explained for suspension bridges)*

# Bridge Construction

- Cable Stayed Bridge: Cable Installation



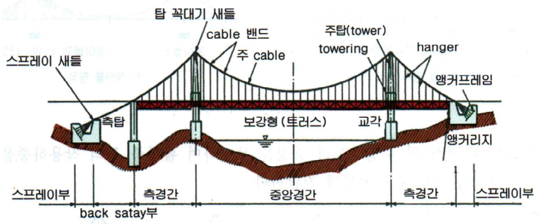
(a) HDPE 파이프 반입
(b) 주탑 작업대 설치
(c) 주탑의 앵커정착구 설치
(d) DECK 앵커정착구 설치
(e) HDPE PIPE 연결
(f) HDPE PIPE 인양
(g) HDPE PIPE 설치
(h) 강연선 삽입
(i) 앵커정착구에 강연선 삽입
(j) 주탑부 강연선 인장
(k) 보호용 캡(cap) 설치
(l) 설치 완료된 케이블 정착부

# Bridge Construction

- Suspension Bridge (현수교)

# Bridge Construction

- Suspension Bridge (현수교)



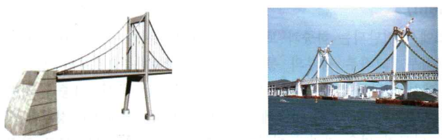



그림. 타정식 현수교(광안대교)

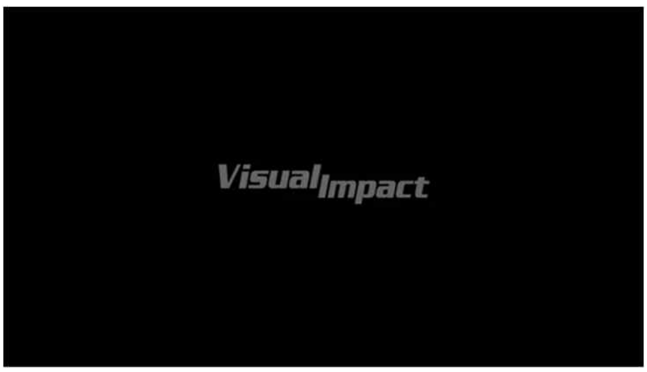
그림. 자정식 현수교(영종대교)

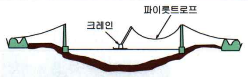
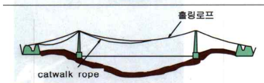
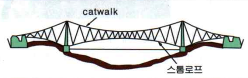
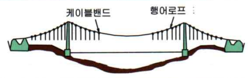
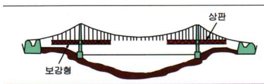
***Earth-anchored**:*
*Main tower → main cable → hanger → girders*

***Self-anchored**:*
*Main tower, temporary piers → girders → main cable → hanger → remove temporary piers*

# Bridge Construction

- Suspension Bridge (현수교)



| 개 략 도 | 주요 공종 |
|---|---|
|   | ① 기초공사 |
|   | ② 탑 가설 및 앵커리지 공사 |
|   | ③ 파이롯트 로프(pilot rope) 도해공사 |
|   | ④ 홀링 로프 및 catwalk rope 가설 |
|   | ⑤ Catwalk 바닥 및 storm rope 가설 |
|   | ⑥ 주 케이블 (strand) 가설 |
|   | ⑦ 케이블 밴드 및 행어로프 가설 |
|   | ⑧ 보강형 및 상판의 가설 |

***Pilot rope**: Temporary rope to guide cable installation processes*

***Catwalk**: Temporary working platform for main cable installation processes*

***Storm rope**: Wind protection for the catwalk, can be eliminated with high technology*