Treatment of Concrete Floor Slabs in Early 20th Century Korea

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Abstract

This study aims at identifying the time of advent of the concrete floor and the development of both steel girders and concrete floor structures in the early 20th century in Korea. The subjects of this study include the Seokjojeon in Deoksu Palace, the Bank of Chosen, and the Chosen Hotel which was destroyed. It seems that the advent of concrete floor structures in Korea started with construction of the Seokjojeon in Deoksu Palace at the end of the 1890s. The concrete floor structure was also attempted with steel girders in the Bank of Chosen and Chosen Hotel, which were constructed around the same time. Seokjojeon and the Bank of Chosen used concrete of 12cm thickness with spacing of 75cm after placing corrugated steel plates of 3.6mm thickness between the beams (J.B). The Chosen Hotel used corrugated steel plates between beams at a spacing of 170-200cm, inserted flat bars of 2.54cm width and 0.16cm thickness at a spacing of 23cm, and then laid concrete from 12cm to 24cm in thickness. The Chosen Hotel shows floor structure details including the insertion of flat bars at a specific spacing instead of unreinforced concrete, which could be seen as the initial stage for subsequent reinforced concrete structures.

Keywords: Korean modern architecture; concrete floor slabs; steel girders(beams); corrugated steel plates; flat bars

1. Introduction

The Industrial Revolution which began in the 18th century, brought not only a greater quantity of production but also quality improvements to construction materials. The advancement of construction materials in such ways also presented fundamental changes in architecture and structure. For instance, the production of iron and cement enabled the use of economic and effective architectural structures in comparison to the wood and stone that had previously been used for building construction. The transition to these new materials initially began with the floor structure. Later, steel girders or concrete slabs combined with steel girders eventually led to the further advancement of new structures in which iron and concrete blended with the existing architecture in brick and stone. Although concrete floors using steel girder methods began from the end of the 19th century in the West, it seems that they were mainly introduced to Korea in the early 20th century.

The process of changing the floor structure in brick and stone architecture from the existing wooden floor frame to the concrete floor with steel girders is significant in terms of the history of modern architectural technology. In addition, this method of construction is also considered as the beginning of the reinforced concrete structural system. Accordingly, this study aims at identifying the time of advent of the concrete floor and the development of both steel girders and concrete floor structures.

The subjects for this study include the Seokjojeon in Deoksu Palace which we assume\(^3\) had concrete floors with steel girders for the first time among the extant buildings, the Bank of Chosen which was established in contemporary times but has been repaired a few times, and the Chosen Hotel which was destroyed. In addition to the site investigations for these three buildings, analyses and arrangements have been carried out based on a variety of literature including the construction reports\(^4\) at the time of construction, repair and actual survey reports among others.

2. Advent of Concrete Fireproof Floor Structure

2.1 Production of Iron and Cement

Although the major materials manufactured for the construction field had been handicraft materials including stone, brick and wooden materials among others before the 18th century, those materials started changing to ferrous materials that could be made using industrialized production methods since the Industrial Revolution. The industrialization of iron production started with the use of coke instead of charcoal in Coalbrookdale in 1709 by Abraham Darby, and the mass production of iron became possible with the use of coal from 1750. The use of cast iron for structures first occurred in Alcobaca, Portugal in 1752 when a cast iron pillar supported a chimney, and a span stair was supported with wrought iron in the Palais du Louvre\(^5\). A technician, Saint Fart, first designed the steel floor structure with the use of porous ceramic tiles and forged iron joints in France in 1785, and Ango designed joist beams with a combination of forged iron materials in the same year and used them on the floor of Punchcock House on the outskirts of Paris\(^6\). The development of iron progressed from cast iron to wrought iron and then to steel before steel production was put into practical use by Bessemer in 1856. This iron did not make its appearance in a type that changed the construction methods of steel structures at once, but started in a manner to change part of the existing materials for buildings\(^7\).

Although wooden beams were hung on brick walls and the floor then formed with joist beams and floor boards before the use of steel girders, the concrete floor emerged from the possibilities of slabs for the production of steel girders. As shown in Fig.1.(a), steel girders are hung on the walls to both the left and right and then the brick arch or corrugated steel plates are directly installed between steel girders, if the span is 1.5-1.8m. As shown in Fig.1.(b), beams are supported

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1824 UK, Joseph Aspdin - Patent for the production method of cement
1827 UK, W. Hobbs - First patent for concrete pavement
1844 UK, W. Fairbairn - Patent for the engineering method of concrete
1848 France, J. L. Lambot (1814-1887) - Produced concrete plates
reinforced with iron rod meshes
1854 UK, W. B. Wilkinson (1819-1902) - Patent for the floor and
ceiling of reinforced concrete structures
1861 France, F. Coignet (1814-1888) - Built a house with concrete
walls with metallic meshes
1865 First concrete road construction in Scotland
1866 France, J. Monier (1823-1906) - Patent for the method of
inserting iron meshes in cement
1870 USA, D. Sailor - Started the production of cement in
Pennsylvania
1872 Japan, Constructed a cement mill
1875 Japan, Plasticizing Portland cement for the first time
1876 USA, P. O. Sailor - Constructed a cement mill in Cobray,
Pennsylvania
1877 France, J. Monier - Invented the reinforced concrete crosstie
1879 France, F. Hennebique (1843-1921) - Announced the theory of
reinforced concrete, designed floor plate
1884 USA, Establishment of standard test methods on concrete by the
American Society of Civil Engineers
1885 UK, F. Ramsome - Patent for the granulation of raw materials for
cement
1886 Germany, C. W. F. Derring - Introduced Maunier type reinforced
concrete
1888 USA, P. H. Jackson - First patent in USA for P.S. concrete
1890 USA, R. Ransom - Designed T girder, deformed bar
1895 F. Hennebique - Designed the reinforced concrete structure for
the spanning of Charles VI in Silkoon
1900 UK, Established the Portland Cement Industrial Association

2.2 Concrete Floor Support Methods

The ends of floor beams under steel girders are joined to
iron pillars or wall girders. When steel girders are installed
in the brick walls, template stones are installed which allows
for the expansion and contraction caused by temperature
changes in the girders as the areas surrounding the girders
are either filled with bricks or left empty. The ends of
the girders are not built into the wall but are strongly fixed
with the connection to the wall by attaching ironwork to the tips
of the girders. When template stones are used depending on
circumstances, template wrought iron or steel plates are used
as well.

The concrete is placed between steel girders, and is
supported by either brick arches, terra-cotta, or corrugated
steel plates. The use of brick arches began a comparatively
a long time ago. Steel girders are first placed about 1.5m
apart, a brick arch (in 0.5B) is built and then the concrete
is placed on top of these structures. In order to counteract
the horizontal force of the arch on the girders, steel girders
1.2-1.5m apart are connected with bolts in 1.2-1.8cm
(Fig.3.(a)). The sugar refinery (1840) in Bewlay, Moss by
William Fairbairn (1787-1874) was constructed to support the
concrete floors with brick arches between steel girders in I type section. The use of terra-cotta is specific to each
type as it can incorporate indefinite types. Fig.3.(b) shows an example and the top is covered with concrete.

Fig.3(c) shows that corrugated steel plate is used as an
arch instead of brick and the fireproof structure is formed with the placement of concrete on top of it.

The connection to steel girders with bolts is the same as in a
brick arch. The use of a flat steel plate can also be applied instead of an arch type. In such a case, the corrugated plate
should have especially high gulleys. In addition, tile waste, concrete or coal ember concrete is applied to alleviate the
weight of the floor with high hardness in order to maintain the
fireproof characteristics of the concrete used for the floor
(Fig.3.(d)). Only a short span can be used because a concrete
floor would weaken the strength of concrete in the beam and
the thickness would become greater6.

The building of the Ministry of Navy (1894) designed by Josiah Conder (1852-1920) in Japan is thought to be the
first architecture to use such a concrete fireproof floor structure9. Other representative buildings include the main
building of the Bank of Japan10 designed by Tatsuno Kingo
(1854-1919)11, which started construction in 1890 and was
completed in 1896, the Tokyo Chamber of Commerce12
(1899), and the Osaka Appeal Court (1900, Kouzou Kawai), etc.

Fig.1. Arrangement of Steel Girders
(Industrial Dictionary, 1909-11)

Fig.2. Floor Structure of the Sugar Refinery in Bewlay Moss
(Theory of Modern Architecture, 1976)

Table 1. Advent and Progress of the Concrete Floor Structure at
the End of the 19th Century

| Year    | Engineering Science and Technology for the Concrete Floor Structure |
|---------|-------------------------------------------------------------------|
| 1876    | France, W. Golam - Patent for the production of wet cement        |
| 1877    | USA, F. O. Sailor - Constructed a cement mill in Cobray, Pennsylvania |
| 1878    | Japan, Constructed a cement mill                                  |
| 1879    | USA, P. H. Jackson - First patent in USA for P.S. concrete        |
| 1880    | USA, R. Ransom - Designed T girder, deformed bar                  |
| 1885    | USA, Establishment of standard test methods on concrete by the American Society of Civil Engineers |
| 1886    | Germany, C. W. F. Derring - Introduced Maunier type reinforced concrete |
| 1887    | USA, F. Hennebique - Designed the reinforced concrete structure for the spanning of Charles VI in Silkoon |
| 1888    | USA, P. O. Sailor - Constructed a cement mill in Cobray, Pennsylvania |
| 1889    | USA, P. H. Jackson - First patent in USA for P.S. concrete        |
| 1890    | USA, R. Ransom - Designed T girder, deformed bar                  |
| 1895    | USA, P. O. Sailor - Constructed a cement mill in Cobray, Pennsylvania |
| 1896    | USA, F. Hennebique - Designed the reinforced concrete structure for the spanning of Charles VI in Silkoon |
| 1897    | USA, P. H. Jackson - First patent in USA for P.S. concrete        |
| 1898    | USA, R. Ransom - Designed T girder, deformed bar                  |
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| 1900    | USA, P. H. Jackson - First patent in USA for P.S. concrete        |
On the other hand, the examples which show the development of RC structure applications are the roof of the Echizen dress store which was completed in 1909 and the Tokyo Commerce High School (completed in March, 1916) which adopted the T shape beam. Although RC construction was applied to the ground of the Dduck-do water facility in Korea, considering that Takjbu (度支部) took charge of the overall construction, it is assumed that RC beams and columns were not used in this facility. The example which can be seen clearly in an extant modern building in Korea is a common roof on the left-hand side of the Seoul station building (Historic Relics No. 284), the construction of which started in June, 1922 and was completed in September 1918. The structural drawings show that, unlike the Seoul station web reinforcements were not used and bent reinforcements were replaced by thin metal pins.

3. Concrete Floor Structure of the Seokjojeon (Eastern Building) in Deoksu Palace

It is assumed that Seokjojeon, Historical Relic No. 24, was designed by the English architect, G. R. Harding, around 1898-99. The construction commenced in 1900 and was completed by a contractor called Okurakumi in June 1903 after being temporarily suspended during 1902. When it was completed, there were three stories which totaled over $4,122.51 \text{m}^2$ with living rooms for servants on the first floor, a reception room and a hall on the second floor, and bed rooms and living rooms for the emperor and empress on the third floor. On June 25, 1955, the Army Engineering Corps repaired and restored Seokjojeon, which had been damaged during the Korean War. The repairing construction began on October 28, 1987 to change the use of the building to...
an exhibition center for royal relics. During the repairing process, the steel frame structure on the floor structure of Seokjojeon was discovered\(^\text{19}\). The dimensions of each room on the first floor of Seokjojeon are; ① Storage Room 6.01×8.87m, ② Storage Room 11.61×8.96m, ③ Storage Room 6.01×8.47m, ④ Air-conditioning Room 6.61×4.71m, ⑤ Administration Division 7.70×5.65m, ⑥ The Chief room of the Administration Division 4.82×5.65m, and ⑦ Exhibition Division 7.70×5.65m. The height of each floor is; 2.845m for the first floor, 4.967m for the second floor, and 5.069m for the third floor (Fig.4.).

The following materials were used in the construction: granite stones from places near Changui Gate (Segumjeong) were used for the initial foundation construction, and granite stones from Youngpoong-jeong outside the Eastern Gate were used for the second and third floors. Stones for balustrades on the rooftop and balconies were imported from Mt. Tsukuba in Ibaraki Province, Japan. Cement and glass were imported from an English company Homeringer. Sand and soil were taken from streams in front of the Gwanghwamun Post Office (Seorin Hotel). The interior decoration was done using designs by the English architect, Lovell. The internal piping and heating were done by Crittall & Co. of London, and the internal devices and furniture were arranged by Messis Maple & Co\(^\text{20}\).

As shown in Fig.5., three types of I type steel girder were used in Seokjojeon. These include girders (G) and beams (B or J.B). Girders and beams were used for structures and smaller beams (J.B) were used for the concrete placement. Considering steel girders used on the second floor, a girder of G1 (ℓ =13.0m) in I-350×150×12×24mm was used for the storage room, where as a beam of B1 (ℓ =5.0m, a=2.6m) in I-300×150×11.5×22mm was used for the air-conditioning room. A beam in the same size of B2 (ℓ =6.3m, a=2.4m) was used for both the storage room ① and ②, and B3 (ℓ =5.8m, a=2.6m) for the administration division and the chief room of the administration division. A joist beam in Ⅰ-125×75×5.5×9.5mm was installed either on a girder or beam, but if the span was small, it was installed directly on the brick walls. When a girder or beam was placed on the brick walls, a template stone of 25cm width, 28cm height and 40cm length was placed on the brick wall as shown in Fig.6., and then
either a girder or a beam was placed on top of it and the projected length of the template stone was in the range of 25-30cm.

The floor structure of Seokjojeon reported in the "Survey and Research Report on the Structural Safety of Seokjojeon in Deoksu Palace" in January 1989 suggested that it was reinforced with iron meshes and covered with concrete after setting corrugated steel plates\(^{13}\) on I type steel girders. With a distance of 75cm between spacing beams (J.B), the concrete was poured in an average thickness of 13cm on top of the connection of corrugated steel plates 3.6mm between beams (J.B). (Fig.6.) As shown in Fig.10., the floor concrete is currently placed on the top of the beams (J.B). It is assumed that the concrete was added to the existing concrete floor when repair and restoration were carried out in 1955.

4. Concrete Floor Structure of the Main Building in the Bank of Chosen

The main building in the Bank of Chosen is designated as Historical Relic No. 280. Construction commenced in November 1907 and was completed in January 1912. The building was designed by the Japanese architect, Tatsuno Kingo, and constructed by Shimizukumi. Seokjojeon has one basement floor and 3 stories above ground. Except for the vault, all internal spaces sustained total damage from fire as a result of bombardment in September 1950 during the Korean War. It was restored to near the original shape in 1989, although part of the building was changed by additional construction during the restoration work of January 1958. The building was remodeled in 2001 and is now used as the Money and Finance Museum. The dimension of each room on the first floor according to the "Construction Reports on the Bank of Chosen\(^{22}\) published in January 1912 and "Repair Reports on the Main Building of the Bank of Korea" published in 1989 include: \(\Box \) Guest Hall 29.7 × 18.3m, \(\Box \) Monetary Reception and Delivery Department 29.7 × 9.9m, \(\Box \) Business Reception 9.9 × 28.2m, \(\Box \) Treasury Department 9.9 × 28.2m, \(\Box \) Branch Office of the Document Division 11.5 × 7.3m, and \(\Box \) Check Exchange Room 9.9 × 7.3m. This remodeled building consists of one basement floor and three stories above ground, which is the same as the original structure. The height of each floor is as follows: the basement floor 3.03m (10\(\ell \)), 1 Korean Cheok (\(\ell \)) = 0.303m), Business Department on the first floor 6.06m (20\(\ell \)), Guest Room on the first floor 12.12m (40\(\ell \)), second floor 5.45m (18\(\ell \)), and third floor 3.64m (12\(\ell \)). The height of the main building is 20.91m (69\(\ell \)), and the height of the lightning conductor from the ground is 28.91m (95.4\(\ell \)).

Stones among major materials used in the construction were transferred by electric cars after they were quarried outside the Eastern Gate. The largest stone weighed 13,125kg (3,500\(\ell \)). 1 Korean Gwan (\(\ell \)) = 5.75kg). These larger stones were used for pillars at the entrance or eaves. Bricks produced by the governmental brick mills were used. Wooden materials from Kiso Province in Japan were used for wooden rods or teak woods. Ironworks used in girders and pillars in each floor were manufactured by the Carnegie Company in the USA, and shutters and window frames by Henry Hope Company in the UK. Asano Cement from Japan was used following strict tests and other materials were purchased through dedicated suppliers.

Fig.8. shows the locations for steel girders on the second floor in the Bank of Chosen with reference to the literature\(^{20}\). It seems that girders were placed on the wide span between the brick wall and pillar, and the angle joint was done with beams between girders. It seems that a girder G1 (\(\ell \) = 9.9m) of I = 300 × 150 × 8m was used for the Monetary Reception and Delivery Department\(\Box \) and the same girder G2 (\(\ell \) = 9.9m) for both the Business Department\(\Box \) and Treasury Department\(\Box \). In addition, a girder G3 (\(\ell \) = 7.3m) and G4 (\(\ell \) = 7.3m) in the same size was applied to the Branch Office of the Document Division\(\Box \) and Check Exchange Room\(\Box \), respectively.

Seemingly, smaller beams of a not accurately known size (B, \(\ell \) = 9.9m, a = 2.8, 3.0m) were placed on top of these girders and then beams (J.B) in 1 = 150 × 100 × 6mm...
were installed upon which to place the floor concrete. The installation was presumably done at a spacing of about 75cm when a span of 9.9m was equally divided into 13 segments for the Monetary Reception and Delivery Department(Ⅱ) / Business Department(Ⅲ) / Treasure Department(Ⅴ), and a span of 7.3m into 10 for the Branch Office of the Document Division(Ⅵ) and Check Exchange Room(Ⅱ).25

As shown in Fig.9., the floor was formed of unreinforced cinder concrete after beams (JB) in I-150 × 100 × 6mm were connected to girders with angles after first placing a girder of I-300 × 150 × 8mm was placed first. The bottom area had a camber of about 3cm. Considering the camber of about 3cm here, the concrete was presumably placed after corrugated steel plates were connected between beams35.

As the basement floor and second floor were used respectively for the underground vaults and office spaces, there was no need for space with a larger span for the floor structure of the first and third floor. Accordingly girders were partially used and the concrete floor was formed with the placement of beams between walls. The floor structure on the second floor was said to have had absolute fireproof characteristics with reinforced concrete along with devices to block sound and vibrations.

5. Concrete Floor Structure of the Chosen Hotel

Construction of the Chosen Hotel commenced in March 1913 and was completed in September 1914. It was designed by the German architect, Georg de Lalande23 (1872-1914) and constructed by Shimizu-kumi as a brick and stone structure. The Chosen Hotel was later demolished to construct a new hotel as a joint investment of both the International Tourism Corporation and American Air Lines in the USA in 1967. Unlike the two buildings described previously, detailed design drawings are attached to the "Overview on the New Construction of the Chosen Hotel in Seoul" published on the completion of the Chosen Hotel by the Railway Service of Chosun Government General.

As shown in Fig.11., the floor was formed by unreinforced cinder concrete after beams (JB) of I-150 × 100 × 6mm were connected to girders with angles after first placing a girder of I-300 × 150 × 8mm. The bottom area had a camber of about 3cm35. Considering the camber of about 3cm here, the concrete was presumably placed after corrugated steel plates were connected between beams.

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Chosen Hotel consisted of one basement and four stories above ground. The dimensions of each room on the first floor had a camber of about 3cm here, the concrete was presumably placed after corrugated steel plates were connected between beams.

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The major materials used for the structure were as follows. Stones were carried from Dongdaemun Quarry the same as was done for the aforesaid two buildings and bricks were provided by Mapo Prison or imported from Osaka in Japan. Tiles were imported from Germany and the USA, and cement from Asano and Onoda in Japan. Steel girders for floors and other miscellaneous uses were imported from Germany, the UK and the USA, and copper plates from Osaka in Japan.

Fig.12 (a) depicts the pub and ballroom as the largest hall, where various types and sizes of steel girders were used in the Chosen Hotel. Girders used here include five types such as G2 (II -381 × 143 × 14mm), G4 (III -509 × 163 × 16mm, as a combination of I and II type), G5 (III -509 × 163 × 16mm), G6 (III -458 × 155 × 14mm as a combination of I and II type), G7 (II -509 × 156 × 12mm), which consist of II type. III type as a combination of I type and II type. These girders were placed either between the brick wall and a pillar or between brick walls. It seems that beams of B4 (II -305 × 127 × 9mm) and B5 (III -455 × 188 × 12mm) were placed on these girders, and then beams of J.B1 (2 I -150 × 70 × 6mm), J.B3 (I -178 × 91 × 6mm) and J.B5 (I -203 × 104 × 9mm) were placed later between them for the placement of concrete, respectively. The concrete was laid in a thickness of 12cm and then an additional 24cm was added to the cured parts. Considering these aspects, it seems that corrugated steel plates in the arch were placed between beams (J.B) (Fig.13).

Peculiar aspects of the Chosen Hotel include; the 6 cm concrete cover was applied to protect girders from any direct fire; mortar mixed with a waterproofing agent in advance was applied to the concrete in 0.9-1.5mm (0.3-0.5") thickness for fireproofing and water-proofing purposes.[20] In addition, flat bars (in a thin strap shape) of 2.54cm (1") width and 0.16cm (1/16") thickness were inserted into the floor plate at a spacing of 22.86cm (9") after steel girders were placed as a whole, for the purpose of complete fireproof functions in each floor on the first floor or higher. The mix ratio of cement, sand and gravel for the concrete used in the floor was 1:2.4.[20] The basement floor of the Chosen Hotel consisted of concrete 15cm thick using a combination of 1:3:6 for cement, sand and gravel and the hexagonal mosaic tiles in white were finished with cement mortar. In order to completely combine the concrete, an electrically driven machine with 5 horse power, in other words a concrete mixer, was used.[20] The cement mortar was mixed with a waterproofing agent in order to counteract humidity if the ratio of sand to cement was under 1:3. The floor consisted of joists and wooden floors on the cement mortar that had been processed to be humidity-proof.

6. Conclusions

The following findings could be identified while investigating how Korea was introduced to and developed the concrete floor structure that had appeared with the production of iron and cement in the West and Japan.

First, it seems that the advent of concrete floor structures in Korea started with the construction of the Seokjojeon in Deoksu Palace at the end of the 1890s, which was constructed using slabs along with the stone and brick structure. The concrete floor structure was also attempted with steel girders in the Bank of Chosen and Chosen Hotel, which were constructed at the same time. It can be said that the technology of the concrete floor under steel girders began in Britain (Patent for the engineering method of concrete placement on I type section bolt made of wrought iron by W. Fairbairn) in the 1840s, was introduced by the Ministry of Navy in Japan after the 1890s, and was influential in the construction of the Deoksu Palace in Korea in the 1900s.

Second, considering steel girders used in the buildings, girders of 2 I -350 × 150 × 12 × 24mm and beams (J.B) of I -125 × 75 × 5.5 × 9.5mm were mostly used for the stone building, larger girders in I-300 × 150 × 8mm
and beams (J.B) of 1 - 150 × 100 × 6mm for the Bank of Chosen, and girders of II -381 × 143 × 14mm and beams (J.B) of 1 - 178 × 91 × 6mm for the Chosen Hotel.

Third, considering the methods of concrete floor structure, the Seokjojeon and the main building in the Bank of Chosen used concrete 12cm thick with a distance of 75cm after placing corrugated steel plates 3.6mm thick between beams (J.B). In the Chosen Hotel, corrugated steel plates were placed between beams at a space of 170-200cm, flat bars of 2.54cm width and 0.16cm thickness were inserted at a spacing of 23cm, and then concrete from 12cm to 24cm thick was laid.

The Chosen Hotel shows a floor structure different from the previous buildings including the insertion of flat bars at a specific distance instead of the unreinforced concrete used in the other two buildings, and the concrete covering the girders for fire-resistance among other things, which could be seen as the initial stage for the succeeding reinforced concrete structures.

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