Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 78 (1998)

Artikel: Laong distance underpass construction beneath railway
Autor: Narita. Mashiro / Kaneko, Yuuichi / Fujisawa, Mitsuaki
DOI: https://doi.org/10.5169/seals-59063

Long Distance Underpass Construction Beneath Railway

Masahiro NARITA
Civil Engineer
East Japan Railway Company
Tokyo, Japan

Yuuichi KANEKO
Civil Engineer
East Japan Railway Company
Tokyo, Japan

Mitsuaki FUJISAWA
Civil Engineer
East Japan Railway Company
Tokyo, Japan

Toshihiko NIIBORI
Civil Engineer
East Japan Railway Company
Tokyo, Japan

Summary

In Japan in recent years it has become increasingly common for crossings with operating railways to be made into underpasses, in line with the ongoing maintenance of infrastructure. One construction method that has been used in the past in these cases was to secure space under the railway line by constructing temporary supports under the line or by redirecting it temporarily and then using open excavation. The other method was closed excavation from the side of the line while the line itself remains in place. Of these alternatives the open excavation method has the advantage that it can produce the structure provided there is superior management, but it still has a considerable impact on the existing lines, forcing trains to pass slowly. The areas and lines where it can be applied are particularly limited in cases where traffic on the line is heavy. On the other hand with the closed excavation method the construction method must be determined with close reference to the site conditions and the advantages and disadvantages of each technique. If however the task demands "a method that can be applied to construction of a long structure which crosses the rail track and has little impact on the line" there is, as yet, no method which is ready for practical application and meets these conditions.

The writers have proposed a new method (the pre-cast block lateral tightening method) for constructing a box culvert under a railway line under the restrictions inherent in the closed excavation method. This method has actually been applied to the construction of a crossing under a railway line and this report details the design approach and the results of the construction.

1. Introduction

One method of constructing a box culvert underpass under a railway line is to drive rectangular-section concrete PRC beams, which are fabricated in a factory, into drilled holes as the lateral girders and integrate these to concrete main piles driven in to form the structure. (Figure 1) However, the maximum length of crossing which can be planned under this method is limited by the scale of

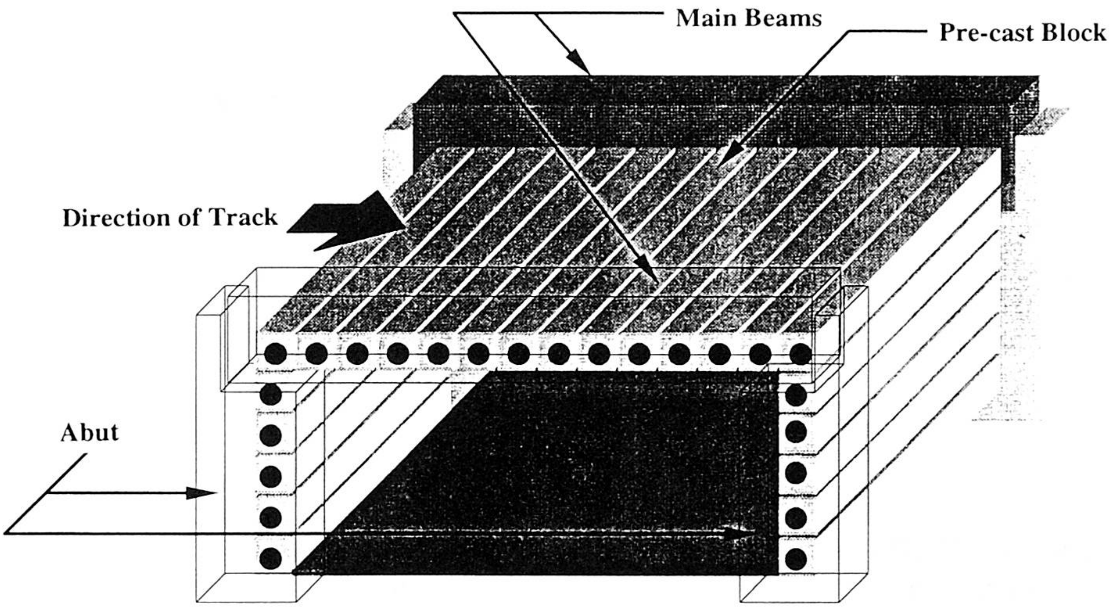


Fig. 1 Conceptional Diagram of Pre-cast Block Method

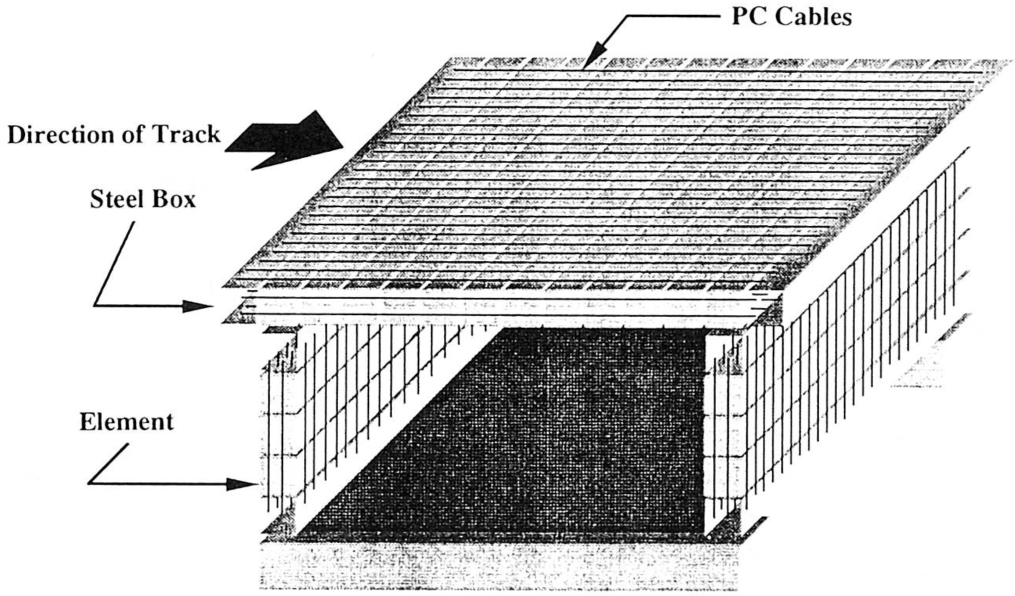


Fig. 2 Conceptional Diagram of Pre-cast Block Lateral Tightening Method

the PRC beams. The method proposed by the writers is the pre-cast block lateral tightening method, and that is to drive in the PRC beams perpendicular to the direction of the track and then introduce a pre-stress in the direction of the track to form a slab beam which can be used as a structural element in the direction of the track (Figure 2). The work involved in inserting and tightening the PC cables in the direction of the track is a drawback of this method, but the only things propelling under the track are small-section concrete elements. There is little impact on the track when the elements are put in place. The structural form on completion is boxes or beams spanning in the direction of the track. There is no restriction on the distance the structure extends across the track.

The fact that the structure is box-shaped means that the main beams running in the direction of the track and large-scale abuts have been required so far, but not necessary any more. These are the merits of this construction method.

East Japan Railway Company has used this method to build an underpass under the JR Sobu line near Kinshicho station where the route of an urban planning road passes under the railway. The structure is a box culvert which spans three spans of approx. 18m in the direction of the track and approx. 32m across the track. The design and construction methods for this structure are reported below.

2. Summary of Construction

The construction project was to build a new box culvert of 60m for a road to pass under a total of eight tracks belonging to our Sobu Honsen and maintenance lines. The section of track concerned is a major trunk route linking the center of the capital with neighboring Chiba prefecture. The traffic is extremely heavy at 880 services per day, particularly in the morning and evening rush hours when the interval between trains falls to two minutes and 25 seconds (Figure 3). There are also some 70 limited express services per day which cannot be delayed by driving slowly over the construction area. Overall the impact on services must be kept to the absolute minimum.

With a view to choosing a construction method with the minimum impact on trains, the pre-cast block lateral tightening method (a closed excavation method) was adopted.
The length of construction across the tracks using the pre-cast block lateral tightening method was 32m (Figure 4) with earth depth being 0.4m from the formation level of track. The soil conditions were, from the surface down, banking, silt and fine sand. All layers are soft and weak with N values of 5 or less. The groundwater level lay 5m below the formation level of track.

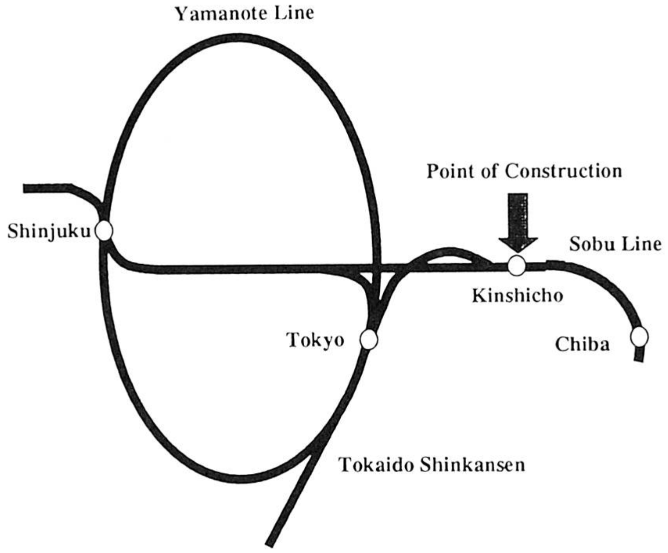


Fig. 3 Location of Construction

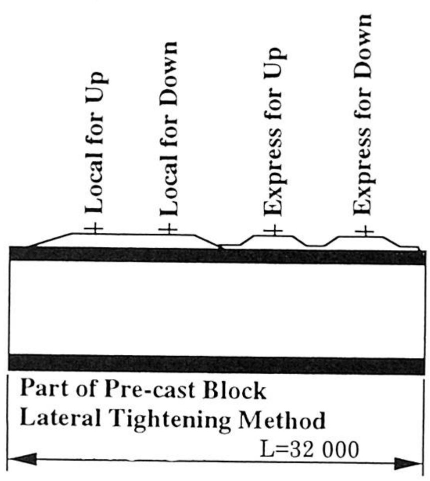


Fig. 4 Crossing View of Railway Line

Figure 5 shows the structural form of the box culvert. The top slab consists of 16 horizontal PRC beams (1,050mm x 1,050mm) and the walls are five PRC columns (950 x 950) driven in vertically. After working steel boxes are pushed into both ends, they are to be bound together in a direction perpendicular to their insertion and create PC slabs. As for the ground under the bottom slab and middle wall, the ground improvement was done as a countermeasure against liquefaction of the fine sand layer. The ease of construction was taken into consideration and concrete piles on site was taken.

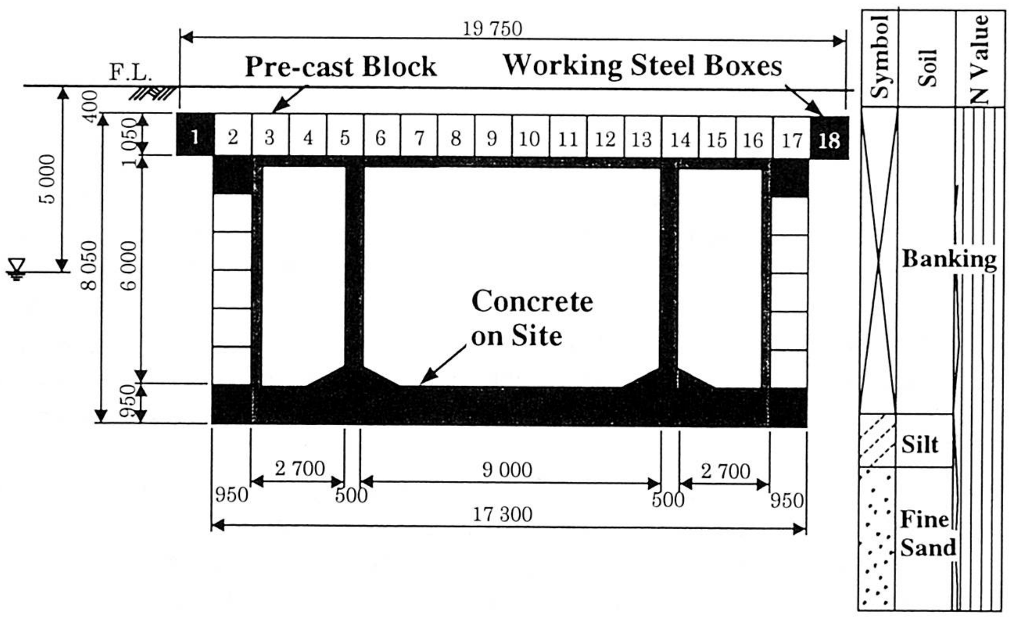


Fig. 5 Sectional View of Slab Beam Type

3. Design

One structural form of box culvert for railway underpasses is the through beam type. This is a method as follows. After PRC beams being pushed into slabs under the track to bear the overburden and side walls to hold back soil pressure, the RC pillars which support the side walls and the PC or RC beams, which hold the slabs are driven into place on site. However the maximum cross-track scale of this form of structure is 20m, dictated by the scale of the PRC beams.
In the method adopted for this project all the beams are bound together by PC cables to form a PC slab, a structural form which is not limited in cross-track length.

3.1 Analytical Model

The concepts behind the analytical model used in the structural calculations are illustrated in Figure 6. The joints between the top slab and the side walls, and the joints between the top slab and central wall were taken as pin joints while the joints between the side walls and the bottom slab were taken as rigid joints. Thus the structural analysis was carried out. The joints assumed to be rigid were those between PC and RC structural elements, the detailing was confirmed by an experiment to exactly evaluate the rigidity of the corners surrounded by the working steel boxes.

3.2 Joints Between the Two Side Walls and the Bottom Slab

The structural form shown in Figure 7 was adopted as a method able to provide the joint rigidity assumed in the design model. The PC steel cables of the side walls and the reinforcing steel of the lower slab are fastened to the working steel boxes and each of the fastened reinforcing bars is lapped to achieve rigidity in the corner close to that of a lap joint.

To evaluate the rigidity of the corner joints and the optimum arrangement of reinforcement, test samples of various forms of joints were constructed at nearly full scale (scale 0.75 ~ 0.85) and subjected to bending load tests. These tests confirmed that the structural performance of the corner joint satisfied capabilities of moment transmission and strength. They also showed that the rigidity of the corner joint can be evaluated by ignoring the steel plate on the compression side and taking 1/5 of the cross-sectional area of the steel plate on the tension side as reinforcement cross section for the RC elements.

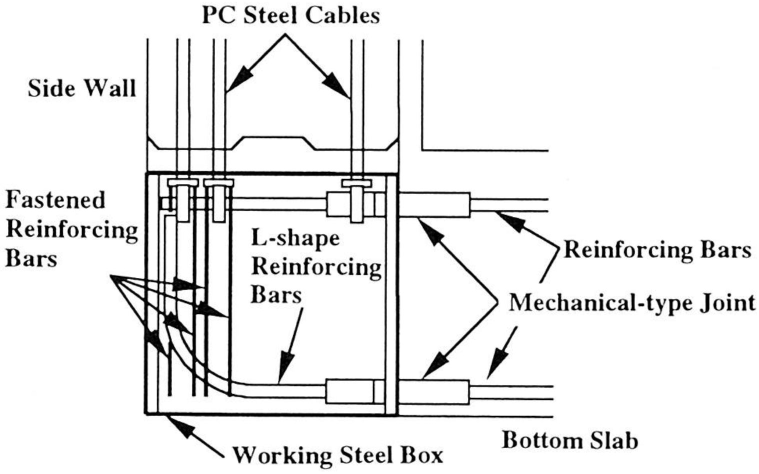


Fig. 6 Layout for Strengthening Reinforcement Bars of Corner Joint

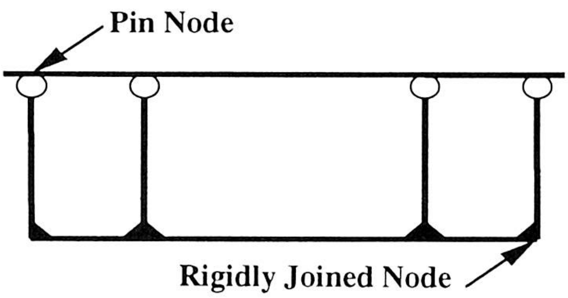


Fig. 7 Conceptional Diagram of Frame

4. Construction

4.1 Insertion of Pre-cast Element (PRC element)

This construction method uses PRC beams as the main structural elements with cables passed through them to apply lateral pre-stress. Increased precision is required to achieve this method. It can be assumed that the soil will include stones and other obstructions. Therefore the substitution method illustrated in Figure 8 was adopted. In this method three temporary steel boxes were driven in parallel. The temporary steel boxes were being pushed behind by PRC beams in the middle part, forcing them ahead. Both the horizontal and the vertical sections were constructed using this method. When the PRC beams are pushed in, their length (32m) is considerable. It was decided to push in 8m sections at a time, linking four together to produce the full length. Each line of four sub-beams was joined together by PC bar to form a single 32m beam.

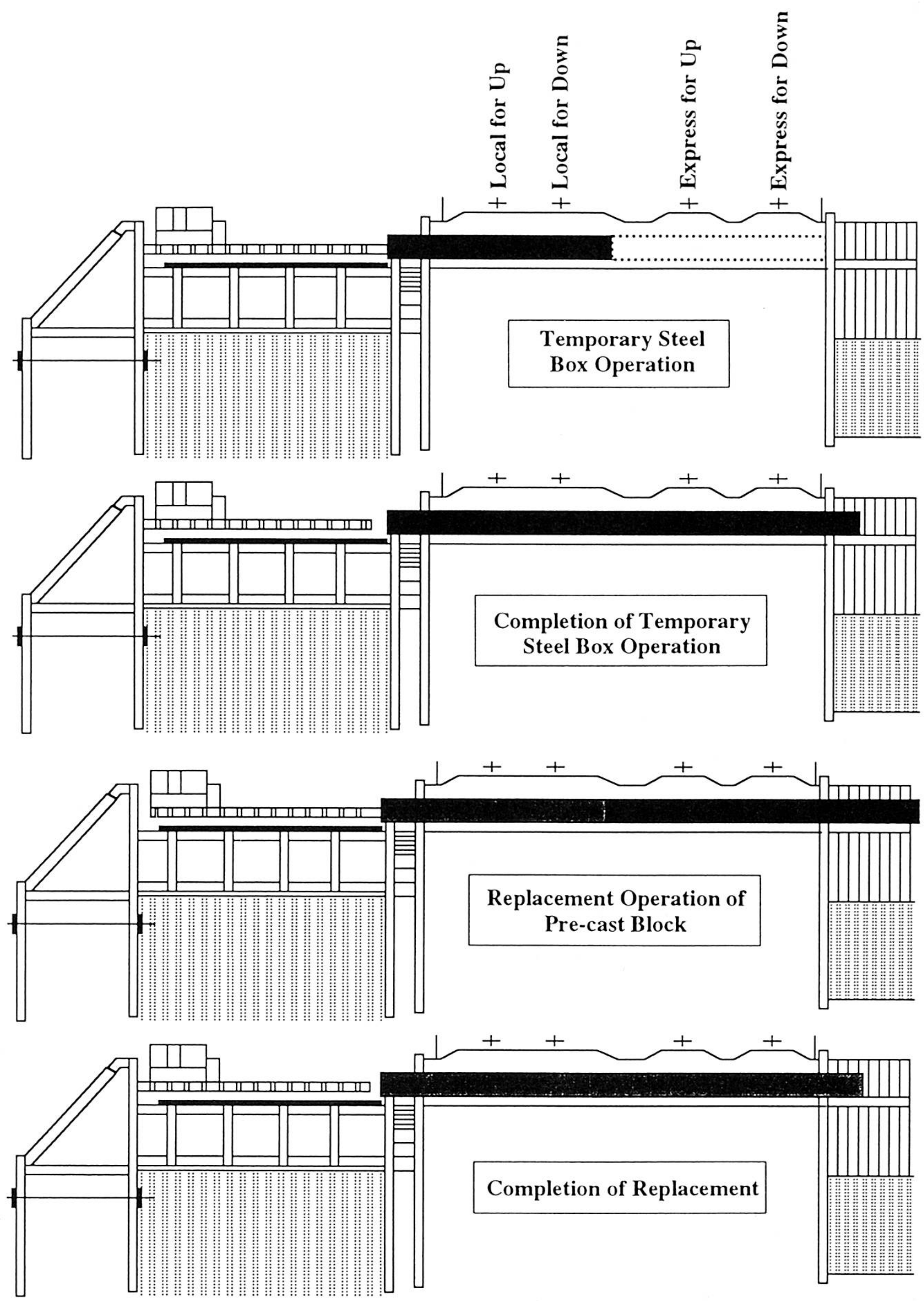
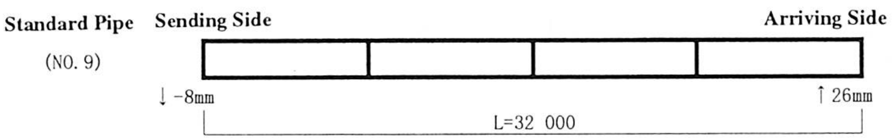


Fig. 8 Sequence of Replacement Construction

Adequate space was required for the operation of passing PC cables through each end of the horizontal and vertical elements and tightening them. Box beams were inserted to provide space. These were filled with concrete after the pre-stress had been applied to the PC cables.
The process of inserting the beams for the horizontal section takes the beams in the center of the horizontal section as the standard box and, as the shallow soil coverage demands high precision, excavation for this pipe proceeds by hand. Excavation for other temporary steel boxes are excavated by machinery. The precision of the base pipe's placement is, at the insertion end, 8mm to the left and 8mm down while at the far end it is 26mm to the right and 26mm up. Therefore the degree of precision both vertically and laterally was 1/940. The precision results for the top slab beams are shown in Table 1. Despite the great length of the construction at 32m the target accuracy (1/500) was achieved in even the worst case. This seems to indicate the validity of the substitution method.

No. of Beams	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sending Side	-35	-33	-23	-18	-16	-12	-10	-7	-8	-9	-12	-11	-8	-7	-11	-10	-14	-14
Arriving Side	28	26	26	26	18	22	24	32	26	22	20	22	22	19	14	17	17	21
Precision (1/○○)	510	540	650	730	940	940	940	820	940	1030	1000	970	1070	1230	1280	1190	1030	910

Unit (mm), (+) is on the right, (-) is on the left



Result for Precision of Perpendicular Direction (Standard Pipe only)

Table 1 Results for Precision of Horizontal Direction (Top Slab Beams)

For the vertical sections temporary steel pipe sections linking with the horizontal sections were drilled into place and connected in place of the working box beams. Then the temporary steel pipes were sequentially pushed in and replaced by the PRC beams so that the pipe sections replaced the working box beams at the bottom as well.

The pushing in of temporary steel pipe sections in both the horizontal and vertical sections, and their later replacement by PRC beams, was conducted at night after the cessation of train services (a period of approximately 3.5 hours/day). Therefore the construction period for one PRC beam was approximately seven days for the insertion of the temporary steel pipe sections and three days for substitution with the PRC beam, a total of ten days per beam.

4.2 Lateral Pre-stressing

After the PRC beams have been pressured into place, PC cables are inserted and a pre-stress applied to enable use of the PRC beams as a structural element in the perpendicular direction against insertion. The PC cables are arranged as shown in Figure 9. The cables themselves are Afterbond PC steel cables (1T21.8) inner grouted into sheathes and an outer grout is applied between the PRC beam and the cable after the time of insertion. Tension was applied from one side only, from the right in the case of the top slab beams and from the top in the case of the side wall beams. A tension of 43tf was applied to each cable. The introduction of tension forces was based on control value of ±5% of extention volume against planned load of PC cables, and pre-stressing work was carried out to keep

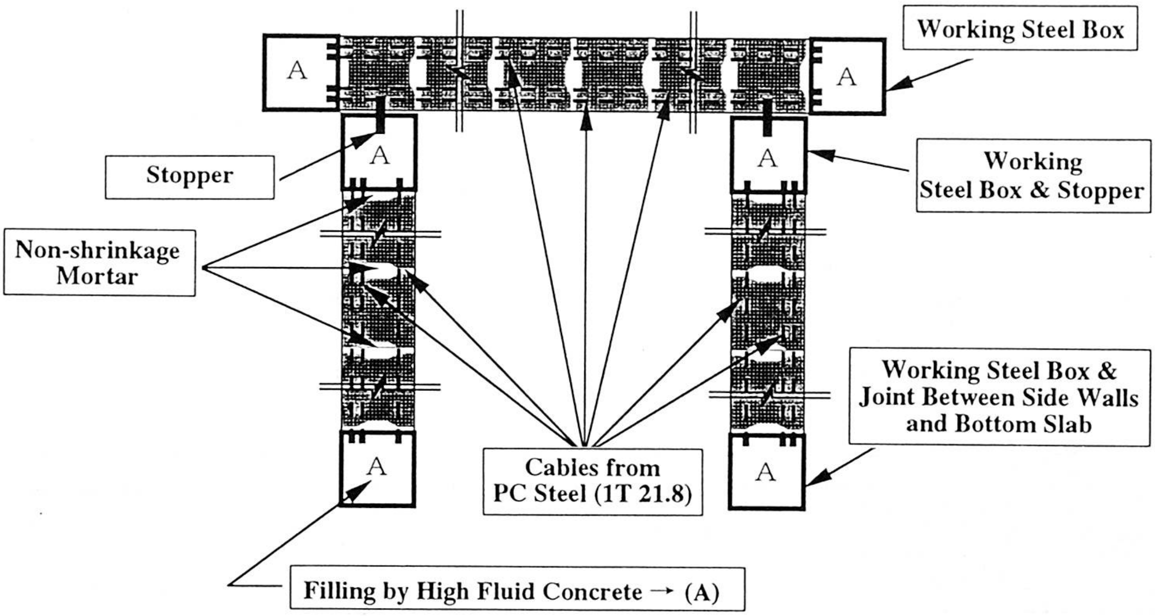


Fig. 9 Layout of Cables

extention volume within the control value. The planned tension forces and the results of construction are shown in Table 2.

The number of cables inserted in this process was 1,196. Of these 428 were in the top slab beams and all tightened mechanically. The process of inserting the cables by machine was rehearsed on a full-scale model to confirm the practicality of the insertion method. The 768 cables in the walls were inserted and tightened by hand. The record of construction results for both the walls and the top slabs is shown in Table 3. The daily number of cables processed in the top slab was approximately twice that for the side walls, which indicates the efficacy of mechanization.

For the other elements to be integrated by the PC cables, all the joints between elements must be filled with mortar. In this case it was anticipated that filling the entire 32m length of the joints would not be possible. The mortar insertion method and mix proportion were confirmed in advance on a scale model.

	Setting Value	Measured Value	Remark
Maximum Load	42.6tf	42.6tf	
Growth Volume	Error is within ±5% for 37mm (Approx. 35mm~39mm)	Maximum Value 39mm Minimum Value 35mm Average Value 37.1mm	Maximum load is fixed for top slab and side walls by equipment.

Table 2 Result of Pre-stressing

Parts of Construction	Cable extention (m/pce.)	No.	No. of days for construction	Work per day			Remark
				Cable extention	No. of the inserted	No. of pre-stressing	
Top Slab Beams (automation)	17.65	428	18	420m	24	25	Side walls were constructed by two formation.
Side Walls (human power work)	6.05	768	20	230m	50~80	80	

* (Total of both sides)

Table 3 Comparison of Construction

5. Conclusion

In the future the number of underpass constructions under busy railway lines can be expected to increase. In order to meet the demands of a wide variety of construction conditions East Japan Railway Company is examining a number of other construction methods in addition to the box culvert method described above. These include design and construction methods for ring-type culverts, methods for constructing the whole body by inserting elements on the part of bottom slab, and methods of using cheaper steel elements in place of concrete elements.

Leere Seite
Blank page
Page vide