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RECOMMENDED PRACTICE FOR PUMPING CONCRETE

Working Group on Recommendations for Pumping Methods in the Subcommittee on Construction Practice

Jiro MURATA, Chairman　　Ei-ichi TAZAWA, Secretary

Committee Members
Hiramasa AOKAGE　Takashi KIMURA　Hiroji KIKUKAWA
Morio KURITA　Masaharu SAKUTA　Masanobu SAKAMOTO
Kazuo SUZUKI　Nobuo NAGAO　Norihiko MIURA
Kazuie YAMADA

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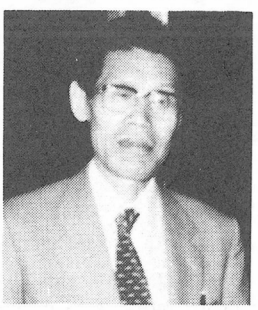
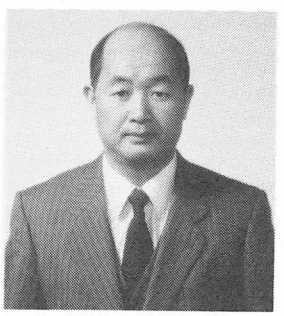
SYNOPSIS

The Concrete Committee of the Japan Society of Civil Engineers (JSCE) organized Subcommittee for the Research on Construction Practice in 1982, when JSCE was entrusted to make researches for advanced techniques applicable for concreting practice by private companies.

The Subcommittee has been organized by four working groups, namely groups for measurement of properties of fresh concrete, for mixing, for vibration and compaction and for Recommendations for Pumping methods. The recommended practice was drawn up in 1985 by the releavant working group.



Jiro MURATA



Ei-ichi TAZAWA

Jiro MURATA is professor of civil engineering at Tokyo Metropolitan University and is chairman of the Subcommittee for the Research on Construction Practice.

Ei-ichi Tazawa is professor of civil engineering at Hiroshima University. He is member and secretary of the Subcommittee for the Research on Concrete Practice.

RECOMMENDED PRACTICE FOR PUMPING CONCRETE

By the Working Group on Recommendations for
Pumping Methods in the Subcommittee on Construction Practice

CHAPTER 1 GENERAL

Article 1 Scope

(1) This Recommended Practice presents general standards with regard to matters necessary to consider in concrete work in which pumping methods using a concrete pump is involved.

(2) Works not stipulated in this Recommended Practice shall comply with the JSCE Standard Specifications for Concrete and the Proposed Related Recommended Practices.

(Commentary)

(1) Recommended Practice for Pumping Concrete applies to the site work of reinforced or plain concrete which involves forcing fresh concrete into a piping using a concrete pump to feed it to a placing site. However, the pumping of mortar in prepacked concrete work, etc. and of cement paste in various grout work is excluded from the scope of this Recommended Practice.

Although intended chiefly for the piston type and squeeze type concrete pumps, this Recommended Practice may be applied to pumps of any other type in which a mechanical means directly pressurizes the concrete.

(2) In this Recommended Practice it is intended to avoid as far as possible the duplication of the JSCE Standard Specifications for Concrete and to describe only matters especially necessary for concrete work in which a concrete pump is used. Accordingly, for matters not described in this Recommended Practice, the JSCE Standard Specifications for Concrete and the Proposed Related Recommended Practices should be followed.

Article 2 Quality of Concrete

Concrete with which a work using a concrete pump is performed shall have sufficient workability, and prescribed qualities not only during work but after hardening.

(Commentary)

It is a matter of course that the fresh concrete should have enough pumpability for concrete work using a concrete pump. However, to assure required quality of concrete after hardening, pumping must be followed by a series of proper operations. Accordingly, it is important to determine workability taking into consideration all the operations necessary for concrete work such as placing, compacting, finishing, etc. Further, beside workability, the fresh

concrete must have proper qualities at the time of concrete work such as air content, weight per unit volume, temperature, setting characteristics, etc., and especially, the use of a concrete pump must not exert a great influence on these qualities. The mix proportion of concrete should not generally be determined taking only the pumpability into consideration, because it may exert a harmful influence upon the quality after hardening. Therefore, it is necessary to determine the mix proportion of concrete with full account taken of the quality at the concrete work as well as after hardening.

Article 3 Definitions

Terms used in this Recommended Practice are defined as follows:

Discharge rate – Quantity of concrete per hour discharged from a concrete pump

Theoretical discharge pressure – Pressure at which a piston of the concrete pump forces out concrete, and which is calculated by the main oil pressure of the concrete pump

Discharge pressure of pump – Actual pressure at the outlet at which a concrete pump forces out concrete

Pressure drop – Differential pressure per meter along a horizontal pipe caused by the flowing concrete

Pumping load on concrete pump – Pressure at the outlet of a concrete pump during pumping of concrete

Equivalent horizontal length – Equivalent length of vertical pipes, bent pipes, taper pipes, flexible hoses, etc. converted to a horizontal straight pipe that is equivalent in pressure drop

Equivalent horizontal distance – Equivalent distance which consists of actual lengths of horizontal parts of a pipeline and the equivalent horizontal lengths in case a pipeline includes vertical pipes, bent pipes, taper pipes, flexible hoses, etc.

(Commentary)

Fundamental terms to be used for pumping of concrete are defined. After these terms have been established by this Recommended Practice, the same definitions would be used in the specification published by the Architectural Institute of Japan.

CHAPTER 2 WORKING PLAN

Article 4 General

A plan on manufacturing, supplying, pumping, placing, compacting, protection, quality control, etc. shall be established prior to start of the work in order to assure required quality of concrete and obtain the approval of the Engineer.

(Commentary)

When adopting the concrete work in which a pumping method using a concrete pump is involved, it is necessary to recognize that this method is liable to cause defects of concrete due to material segregation, poor compacting, cold joint, unevenness of reinforcement due to treading upon it, etc. and to study merits and demerits relative to the other method of casting concrete.

The working plan for concrete work must be worked out which can assure such performance of the concrete as the required strength, durability, water-tightness, fine appearance, etc. as economically as possible.
The work for concrete structures consists of a series of working procedures such as measuring, mixing, transporting (supplying and pumping), placing, compacting, curing, etc., each being closely related to the quality of concrete. Accordingly, work carried out on the basis of a proper working plan will assure concrete of a good quality.

Section 1 Basic Plan

Article 5 Working Organization
The working organization shall be established so that the concrete work can be performed as planned, and the members, persons in charge and the scope of responsibility of each organization as well as the communication means of information shall be clearly stated.

(Commentary)
In concrete work, persons skilled in many types of work are involved in the series of operations, and furthermore it is necessary to complete required operations within a limited time before concrete begins to harden. Therefore, it is very important to clarify the assignment of the parts in operations to the persons in work and the scope of their responsibility, and to establish the communication means by which instructions and information during work can be smoothly transmitted among the involved persons in work.
It is necessary for those concerned with the planning or execution of concrete work to have sufficient knowledge of concrete with experience in practicing it. Although the level of required knowledge and ability, the extent of practical experience, the members of operation, etc. vary with the scale and importance of work, the contents of operation, etc., it is generally better to select such persons from qualified engineers (specialized in concrete work). Those engaging in pumping operation shall have sufficient technical ability to cope with various situations during pumping operation. This kind of guidance and training of ability is carried out in the technical institute held by the All-Japan Liaison Council of Concrete Pumping Trade Association. Accordingly, it is desirable to select the pumping operators from those having a regular qualification (concrete pumping technicians) or those equal or more to them in technical ability.

Article 6 Temporary Work Plan
The temporary work plan with regard to forming, timbering, transporting, placing, compacting, curing, etc. shall be established so that the concrete work can be performed safely and as planned.

(Commentary)
The necessary temporary equipment for concrete work is as follows:
1) Pipes for feeding concrete
2) Scaffolding and passage ways for operation
3) Safety equipment
4) Curing equipment
5) Water-supply and drainage facilities

6) Electric equipment
7) Correspondence and communication equipment
8) Lifting apparatus or hoists

In addition, it is better to take into consideration in advance the place where the feed pipes are to be cleaned after completion of pumping and the ground where concrete not conforming to the requirements as to quality is dumped.

Article 7 Transporting Plan and Placing Plan

(1) A plan on transporting of concrete shall be worked out so that the supplying and pumping of concrete can be performed smoothly, taking it into consideration to minimize the quality variation of fresh concrete.

(2) Partitioning of casting blocks shall be performed giving enough consideration to the supplying capacity of concrete, pumpability, work schedule, configuration of the structure, placing capability, formwork, construction joint etc.

(3) The placing order and placing speed of concrete shall be planned considering the configuration of structure, supplying capacity of concrete, compacting capability, strength of formwork and timbering work, etc.

(Commentary)

(1) The supply of concrete shall be planned so that concrete can be supplied quickly and without delay to minimize the variation in workability due to material segregation, slump loss, etc. In the transporting plan it is important to take it into consideration to keep the balance among the supplying capacity of concrete, pumpability and placing, and compacting capability.

(2) Even if partitioning of casting blocks is performed giving consideration to the reasonable amount of concrete placed at a time while fully studying the items stated in this article, consideration for the cracking of concrete due to temperature is also necessary in the case of mass concrete.

(3) The placing order and placing speed of concrete shall be planned so that the formwork and timbering work are not given such an excessive deformation as to exert a harmful influence upon the preplaced concrete, and that the configuration and dimensions of the completed structure are not different from the required ones. Furthermore, consideration shall be taken not to cause defects such as cracking due to settlement, cold joint, insufficient compacting, etc.

Article 8 Quality Control Plan and Inspection Plan

The quality control plan and inspection plan shall be established in order to construct economically concrete structures having necessary quality.

Article 9 Countermeasures against Unexpected Matters

The countermeasures against unexpected matters during concrete work such as rainfall, snowfall, trouble of concrete pump, clogging, breakage of formwork or timbering, etc. shall be taken into consideration in advance. Further, the countermeasures shall include safety measures for workers.

Section 2 Pumping Plan of Concrete

Article 10 Pumping Plan

(1) The plan for pumping concrete shall be worked out so that the required quality of concrete can be obtained by studying the pipeline layout plan and by selecting the concrete pump of a suitable type and appropriate pumping conditions.

(2) The countermeasures to meet the environmental protection requirements, such as those against the noise generated during pumping concrete, against splash of concrete and the waste disposal of wash water from concrete pump, etc. shall be taken into consideration, if necessary.

(Commentary)

(1) When the plan for pumping concrete is worked out, the following shall be taken into consideration.

1) Location where the concrete pump is placed
2) Piping
3) Type and number of concrete pumps
4) Placing quantity and pumping speed of concrete

The above items must be studied interrelatedly. For instance, depending upon piping conditions, the type and number of concrete pumps required may vary. Further, the enlargement of piping diameter may reduce pumping load, affording margin to the performance and number of concrete pumps. Furthermore, if the placing speed is set to a large value, in some instances, all the other items must be entirely restudied. Therefore, it should be endeavored to work out a reasonable and wholly well-balanced pumping plan. Something lacking in the pumping plan of concrete may cause, for example, the following troubles and result in the defect of concrete structure itself.

1) Concrete having required quality cannot be placed.
2) Cold joint occurs because of the prolonged placing time interval due to rearrangement of piping etc.

Article 11 Pipeline Layout Plan

(1) The pipeline layout plan shall be made taking into consideration the configuration of ground, distance and difference in elevation between the supplying site and placing site of concrete, smooth supply of concrete, and easy concrete placing, supports, relocation and removal of pipes.

(2) The concrete pump shall be installed in a location where the pump can be safely installed, concrete easily supplied and piping easily laid out.
Facilities, such as water-supply, lightening, etc. shall be installed, if necessary, considering safety and other operations.

(3) The diameter of pipe shall be determined taking into consideration the kind and quality of concrete, maximum size of coarse aggregate, type of the concrete pump, pumping conditions, etc.

(4) Tapered pipe having as gradual a taper as possible, and bent pipes having as large a radius of curvature as possible shall be selected.

(5) Water-washer or air-cleaner necessary to clean the concrete feed pipe shall be installed, and sometimes check valves, etc. shall be installed on the piping.

(Commentary)

(1) The most important matter in the pipeline layout plan is to shorten the distance of piping as short as possible and to reduce the number of bends as few as possible. This is important to reduce the pumping load covering the whole of piping, and to prevent the clogging of pipes.

(2) The location where the concrete pump is installed shall be, if possible, so planned that two concrete mixer trucks can be stationed simultaneously. Thus, the time required for changing mixer trucks is shortened, enabling smooth concrete placing operation. Further, the effect to lecrease the variation of quality of concrete can be expected.

(3) It is desirable to determine the diameter of concrete feed pipe after studying the matters shown in the Commentary of Article 13.

(4) The tapered pipe having as gradual a taper as possible is less dangerous to clogging. In the vicinity of tapered pipes, the variation in velocity distribution inside the pipe occurs, and the pressure drop in the piping becomes high, and further clogging is liable to occur. In general, to reduce the diameter of a tapered pipe by 1 inch (2.54 cm), the tapered pipe is required to be as much as 1 m long. As to a bent pipe, similarly, variation in the velocity distribution occurs inside the pipe, and clogging is also liable to occur in this part. Therefore, it is better to use a pipe having as large a radius of curvature as possible to prevent these troubles.

(5) For the cleaning method of feed pipes, there are two kinds of cleaning, air cleaning and water washing. Although the equipment required for these operations is usually fitted on the concrete pump, if this is not fitted, an air compressor or water pump and its related attachment should be prepared. In the case of air cleaning, an air compressor must be used, and the pressure is restricted by the maximum pressure (7 kgf/cm^2) of general purpose compressor. Therefore, the distance to which cleaning can be performed is about 100 m. Further, although this system has an advantage that water is dispensable, close attention must be paid since a cleaner piston or sponge ball would spring out from the outlet of piping while cleaning is carried out.
Water washing, is safeter than air cleaning, and further there is a merit that the cleaning distance can be extended because the discharge pressure of a water pump can be taken higher than that of a compressor.

Article 12 Selection of Type and Number of Concrete Pumps

(1) The type of concrete pump shall be selected taking into consideration the kind and quality of concrete, pipeline layout plan and pumping conditions.

(2) The number of concrete pumps shall be determined taking into consideration the required pumping speed and the discharge capability of selected type of concrete pumps.

(Commentary)

(1) The selection of the type of concrete pumps is the most important matter in continuing the smooth operation by using a concrete pump. An appropriate type of concrete pump shall be selected by referring to Article 13, Study on Pumping Conditions.

(2) Even if the number of concrete pumps is determined in consideration of the required pumping speed per unit time and the discharge capability of selected type of concrete pumps, the following must be taken into consideration.

1) Recess time
2) Time required to move piping
3) Waiting time and changing time of concrete mixer trucks

Article 13 Study on Pumping Conditions

(1) The pumping conditions shall be determined taking into consideration the pumping load on a concrete pump and margin factor for clogging.

(2) The maximum pumping load (P_{max}) on the concrete pump shall be determined by the following equation.

P_{max} = (Pressure drop) x (Equivalent horizontal distance)

(3) The pressure drop will be determined depending on the kind and quality of concrete, discharge speed and diameter of pipe, and the values in Fig. 1 and Fig. 2 shall be taken as the standard.

(4) The equivalent horizontal distance shall be calculated by totalizing the actual length of horizontal pipeline and equivalent horizontal lengths of vertical pipes, bent pipes, taper pipes and flexible hoses, for which Table 1 should be referred to.

(5) When the P_{max} obtained by the above procedure from (2) to (4) is 80 percent or less of the maximum theoretical discharge pressure, it shall be judged that the pumping of concrete is possible.

(6) When it is anticipated difficult to pump concrete, a suitable pumping test shall be carried out on as necessary basis. Further, the judgment test may be carried out in advance to estimate the margin factor of clogging, if necessary.

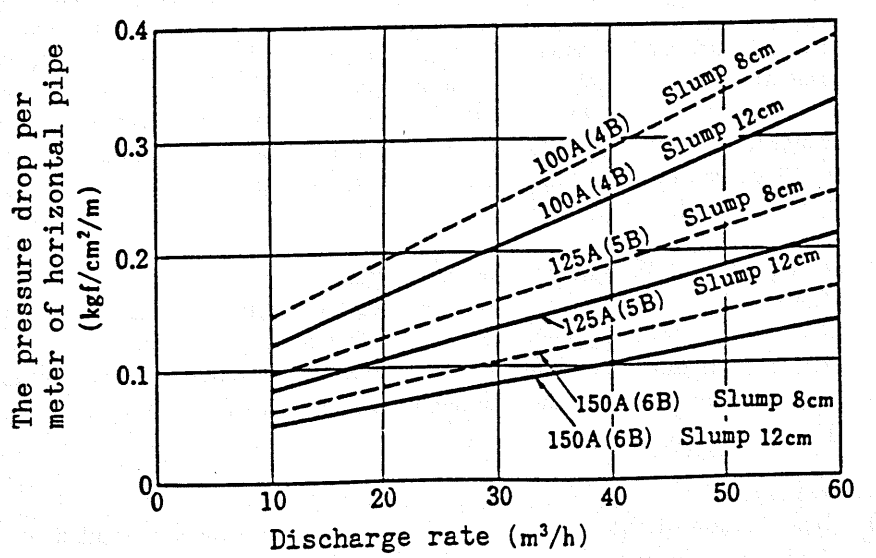


Fig. 1 The standard value of the pressure drop per meter of horizontal pipe for pumping of normal weight aggregate concrete (Maximum size of coarse aggregate is 20-25mm)

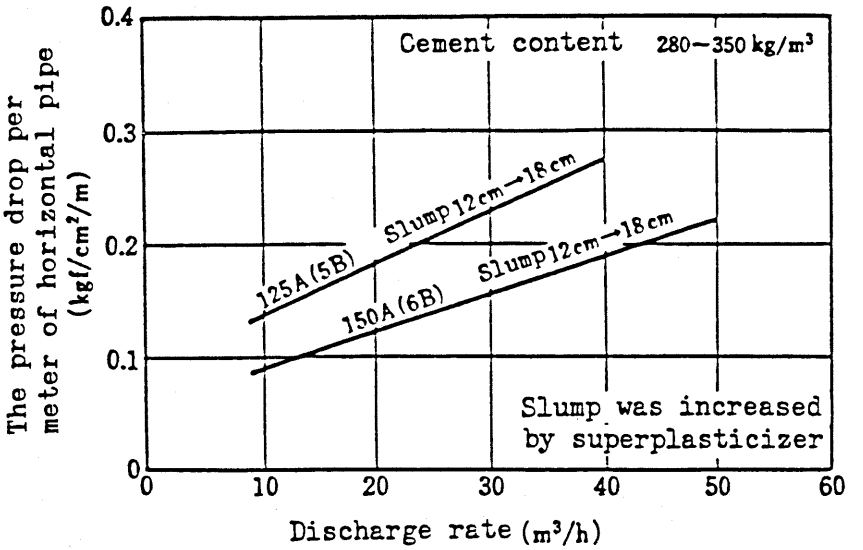


Fig. 2 The standard value of the pressure drop per meter of horizontal pipe for pumping of artificial light weight aggregate concrete

Table 1 The equivalent horizontal length

Item	Unit	Nominal diameter of pipe**	The equivalent horizontal length(m)	
			Mormal conrete	Artificial light weight aggregate concrete
Rising vertical pipe	per meter	100A(4B)	3	-
		125A(5B)	4	3
		150A(6B)	5	3
Taper pipe*	per pipe	175A→150A 150A→125A 125A→100A	3	
Bent pipe	per pipe	90° r=0.5m r=1.0m	6	
Flexible hose	one hose of 5-8m length		20	

* The value is for a taper pipe of one meter length and for a smaller diameter of piping.

** A and B mean the expressions of diameter respectively in mm and inch.

(Commentary)

(1) As to the conditions on which pumping by a concrete pump can be performed, the following matters can be enumerated.

1) Concrete is to have sufficient workability, and to be suitable for pumping using a concrete pump.

2) The theoretical discharge pressure of the concrete pump and actual discharge pressure of the pump is to be sufficient to force concrete in the piping.

Further to the above, as to the conditions for the suitability of concrete itself for pumping using a concrete pump, concrete shall have the following three properties.

1) Fluidity to enable concrete to slide on the pipe wall

2) Deformability in which concrete in the pipe can change its shape

3) Resistance for segregation to resist the timely and locational variation of pressure

The above three properties are delicately affected by one another. For instance, taking the dewatering property as the index of segregation resistance, the resistance in piping has such relationship to the dewatering property that it increases in both excessive dewatering and deficient dewatering conditions, and good fluidity can be maintained in a suitable dewatering condition. Further, although the deformability of concrete depends chiefly on the mix proportion, the mix proportion also exerts a direct influence upon the fluidity and dewatering property.

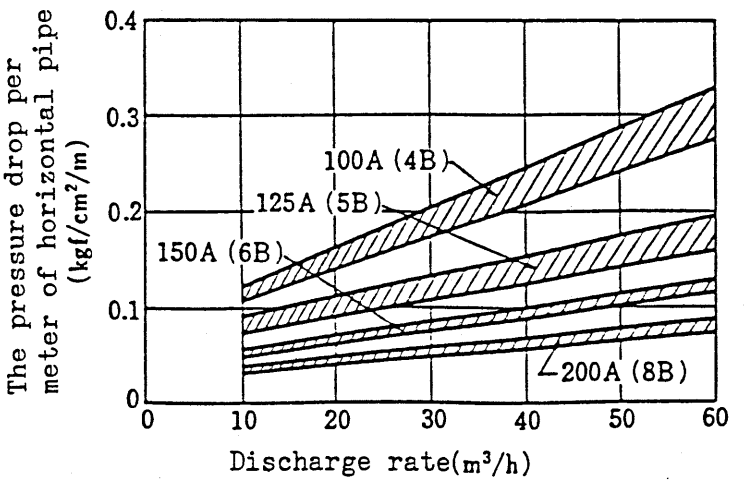
It is generally said that the clogging of concrete in piping often occurs in such cases when unit water content of concrete is small, when unit cement content is small and when the diameter of coarse aggregate is large. In clogged piping the concrete is in a solidified state with water and cement paste portion dissipated. This is the eventual result in which the pressure inside the pipe has raised to a limit, and the symptom of clogging is starting before reaching this state. As the cause of clogging, the segregation of materials and the arching phenomenon among the aggregates can be considered.

(2) The factors having an effect on the maximum pumping load (P_{max}) on a concrete pump are the type and quality of concrete, diameter of piping, conditions of piping, discharge speed, etc. The fundamental procedure for obtaining the maximum pumping load which is adopted here is first to calculate the equivalent horizontal lengths of piping elements such as rising vertical pipes, bent pipes, taper pipes and flexible hoses, and, by adding these to the actual length of horizontal pipeline, all horizontal equivalent piping is assumed. Next, the pressure drop per meter of a horizontal pipe which is determined depending on the factors such as the type and quality of concrete, diameter of pipes and discharge speed is obtained, and by multiplying this and the equivalent horizontal distance, the pumping load is to be obtained.

(3) Taking into consideration the pumping rate per unit time and the operating efficiency, the discharge speed of concrete pump when the concrete pump is continuously operated should be determined. Considering the discharge speed thus determined, slump of concrete and the diameter of pipes, the pressure drop per meter of the horizontal pipe should be determined according to Figs. 1 and 2. Further, the values shown in Fig. 1 are those in the case where the maximum size of coarse aggregate is 20–25 mm, and when the maximum size is 40 mm, extra of 10 percent shall be added over the values in this Fig. 1.

The factors affecting the pressure drop per meter of the horizontal pipe include not only the discharge speed, slump of concrete and diameter of pipe but also many other

factors described in other part of this Recommendation. However, since it is difficult to estimate these factors strictly and quantitatively, in this Recommended Practice it has been decided that the pressure drop per meter of the horizontal pipe is to be determined depending on the above three factors. The results of measurement of pressure drop per meter of the horizontal pipe when ordinary concrete of 12 cm slump is pumped are mostly within the range shown in Fig. 1 of Commentary.



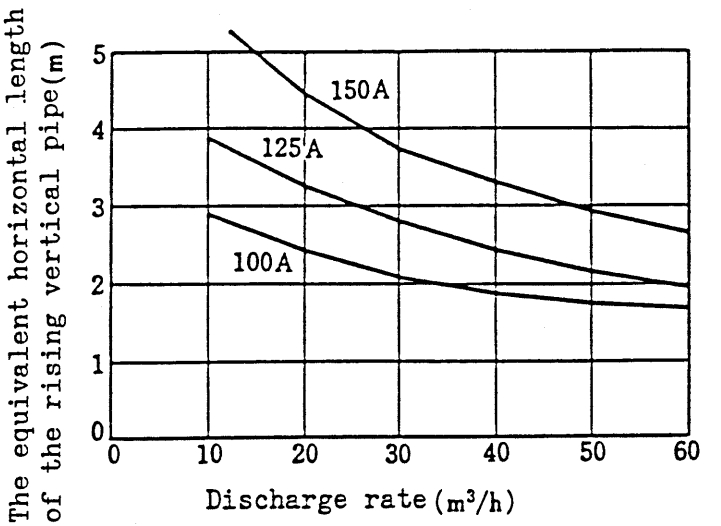
Commentary Fig. 1 The range of the pressure drop per meter of horizontal pipe (Normal weight aggregate concrete, slump was 12 cm)

As obvious from this figure, the pressure drop per meter of the horizontal pipe becomes large as the discharge speed increases, and as the diameter of the pipe becomes small. Further, in these examples of measurement the variation of pressure drop inside the pipe is within a relatively narrow range.

(4) On the equivalent horizontal length, the conception is shown not only in this Recommended Practice but also in the JSCE "Standard Specifications for Concrete", etc. Since the performance of concrete pumps has been generally indicated by the equivalent horizontal distance to which pumping can be performed so far, the excessive value of equivalent horizontal length has often been indicated to assure the safety factor in concrete work. As the factors having effect on the pumping load are divergent and the pumping load cannot be determined only depending on the piping conditions, this Recommended Practice adopts the procedure for obtaining the pumping load by multiplying the equivalent horizontal distance and the pressure drop per meter of the horizontal pipe together. Accordingly, the equivalent horizontal length shown in this Recommended Practice is determined so as to be a value approximate to the ratio of the pressure drop in each piping element to that per meter of the horizontal pipe.

The pressure drop of rising vertical pipe may be considered to be what obtained by adding the pressure difference due to the specific gravity of concrete to the pressure drop of the horizontal pipe. For instance, taking the specific gravity of concrete to be 2.3 and using the relationship of Fig. 1, the equivalent horizontal length of the rising vertical pipe can be obtained as a function of the discharge rate and diameter

of the pipe as shown in Fig. 2 of Commentary. The equivalent horizontal length of the rising vertical pipe in Table 1 is determined on the basis of the above-mentioned data at a little higher value than the ratio of the pressure drop in the rising vertical



Commentary Fig. 2 The equivalent horizontal length of the rising vertical pipe (Normal weight aggregate concrete)

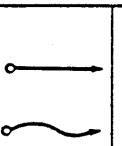
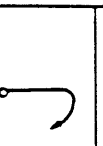
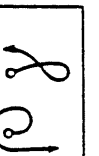
pipe to that in the horizontal pipe. Accordingly, when the pressure drop in the rising vertical pipe occupies a large percentage of the pumping load, the maximum pumping load may be obtained in such a way that the pumping load is first calculated taking the rising vertical pipe as a horizontal pipe and then the pumping load due to the weight of concrete in the rising pipe is added to it. Further, the same procedure may be applied to such piping as is rising slantwise.

On the contrary, in a downward vertical piping, although the weight of concrete acts in the direction to decrease the pumping load, the reduction effect of pumping load corresponding to the weight of concrete is not always expected in the actual pumping conditions. Accordingly, the calculation of the equivalent horizontal distance shall be carried out regarding a downward vertical piping as a horizontal pipe.

As to the pressure drop caused in the vicinity of bent pipes and taper pipes, the examples of measurement are comparatively few, however, it is reported that the pressure drop in the cases of taper pipes and bent pipes is up to 3 times and 6 times the pressure drop per meter of horizontal pipes, respectively. In this Recommended Practice, the equivalent horizontal lengths of bent pipes and taper pipes have been determined to be 3 m and 6 m, respectively on the basis of the examples of these reports. Further, as an example of measurement, the pressure drops of flexible hoses are shown in Fig. 3 of Commentary.

Referring to these data, it can be said that the equivalent horizontal length of a flexible hose with the length of 8 m for example can be regarded as 20 m with a sufficient margin.

(5) Since the pumping load obtained by the above procedure is the pressure exerted on the outlet of the concrete pump, the concrete pump must force concrete by the

Condition of flexible hose(8m)				
Pressure drop(kgf/cm^2)	1.12	1.68	2.00	2.28

Commentary Fig. 3 Exampls of measurement of pressure drop in flexible hoses

discharge pressure of the pump exceeding this pumping load. The discharge pressure of the pump denotes the actual pressure to force out concrete at the outlet. However, in addition to this pressure, the pressure drop caused inside the pumping mechanism of the concrete pump must be taken into consideration at the same time. Although the pressure drop caused inside the concrete pump varies depending on factors such as the kind and type of the concrete pump, its maintenance condition, discharge rate, and slump of concrete, it can be considered to be about 5–15% of the pumping load.

Furthermore, the actual concrete work involves, as a matter of course, variable factors such as the variation or loss of slump of concrete. Taking into consideration the pressure drop and the variable factors on concrete work as mentioned above, it has been decided, in this Recommended Practice, that under the pumping load is 80 percent or less of the maximum theoretical discharge pressure of concrete pump, it shall be judged that the pumping of concrete is possible.

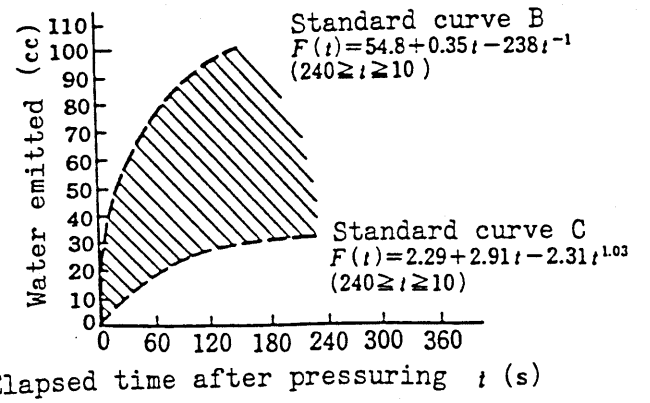
(6) It is anticipated difficult to pump concrete in the following cases:

1) Pumping of artificial light weight aggregate concrete
2) When high-strength concrete and rich-mix concrete is pumped.
3) When large grain coarse aggregate concrete is pumped.
4) When low-slump concrete and poor-mix concrete is pumped.
5) Long-distance pumping
6) Pumping to elevated place

As a countermeasure for such cases, it is most reliable to carry out the trial pumping under the piping condition near to the actual working condition and to observe the operating condition of concrete pump, pumping load, the condition of discharged concrete, etc. If such trial pumping near to the actual working condition is impossible because of the restriction such as the expense, period and condition of site, as a countermeasure in advance, the trial pumping may be carried out under a short piping condition, and the condition at the time of concrete work may be assumed from the condition of this trial pumping.

As a simple and easy test method for estimating in advance the pumpability of fresh concrete, there is a pressurized bleeding test. Several methods for estimating pumpability on the basis of data obtained by this method are proposed, and as one of them, the method shown in Fig. 4 of Commentary can be recommended.

For the estimation of pumpability by this test method, further endeavor is necessary to increase the accuracy of estimate by accumulating many data hereafter. Since the object of the test method is to obtain a fundamental factor contributing to the



Commentary Fig. 4 Condition for good pumpability by pressurized bleeding test (Shaded portion corresponds to good pumpability)

pumpability, namely the movement of water in concrete, it is expected that this test method will be developed to a higher degree reliability.

CHAPTER 3 MATERIALS AND MIX PROPORTIONS

Section 3 Materials

Article 14 General

Materials that have been confirmed as to quality shall be used.

Article 15 Cement

(1) Ordinary Portland cement, moderate heat Portland cement, high-early-strength Portland cement and sulfate-resistant Portland cement shall conform to JIS R 5210, and blast furnace slag cement, silica cement and fly ash cement shall respectively conform to JIS R 5211, JIS R 5212 and JIS R 5213.

(2) A cement other than stated in (1) above shall not be used before it is confirmed for its quality.

Article 16 Fine and Coarse Aggregates

(1) Fine and coarse aggregates shall conform to JSCE Standard Specifications for Concrete.

(2) Crushed sand, blast-furnace slag fine aggregate and coarse aggregate shall respectively conform to the requirements of JIS A 5004, JIS A 5012 and JIS A 5011.

(3) Light weight fine and coarse aggregates shall respectively conform to the requirements of artificial light weight fine aggregate MA 317 and coarse aggregate MA 318, prescribed in JIS A 5002.

(Commentary)
The quality of aggregates, such as grading, shape of grading, and water absorption, have an effect on the pumpability. Further, the fine grain content of fine aggregate and the maximum size of coarse aggregate have an effect. The pumpability becomes better according as the particle size distribution becomes well-disposed, the particle shape is better, percentage of absolute volume is larger and water absorption is less.

(1) It is said that fine aggregate containing more than 15 percent of fine grains of 0.3 mm or less have generally good pumpability. Even if fine grains have an effect to prevent the segregation of concrete, it is better to use the proper quantity of fine grains in the range of 15 percent or more because they have a tendency to increase the unit water content. The particle size distribution of fine aggregate exerts an influence on the unit water content and segregation, and is an important factor to determine pumpability. Therefore, it has been decided to use the fine aggregate conforming to JSCE "Standard Specifications for Concrete".
Further, when fine aggregate containing a small quantity of fine grains is used unavoidably, it is possible to cope with the problem by increasing cement content and the sand-coarse aggregate ratio.

(2) It is said that the pumpability of crushed sand concrete is lower than that of natural sand concrete. The reason is that the water content for obtaining the same slump increases, so that the breeding increases, and the segregation of concrete material becomes liable to occur. Therefore, in the mix design of crushed sand concrete, it is necessary to improve the pumpability by the following means.
1) Use of air-entraining water reducing agent
2) Increase of sand-course aggregate ratio
3) Increase of cement content

Article 17 Admixtures

(1) Air-entraining agents, water reducing agents and air-entraining water reducing agents used as chemical admixtures shall conform to JIS 6204.
(2) Fly ash used as an admixture shall conform to JIS A 6201.
(3) Expansive additives used as admixtures shall conform to JIS A 6202.
(4) Inhibitors used as admixtures shall conform to JIS A 6205.
(5) Super-plasticizer used as admixtures shall conform to the JSCE Quality Standard for Super-plasticizer for Concrete.
(6) Admixtures other than mentioned in (1), (2), (3), (4) and (5) shall be checked and confirmed as to quality prior to use.

(Commentary)

(1) In general, air-entraining agents, water reducing agents and air-entraining water reducing agents enhance the pumpability of concrete, and water reducing agent improves the fluidity of concrete. Entrained air incorporated by air-entraining agent or air-entraining water reducing agent has an effect to enhance the resistance against the material segregation of concrete. Therefore, it is better to use air-entrained concrete basically for concrete pumped.

(2) It may be considered that the pumpability of concrete generally becomes better when fly ash confirming to JIS A 6201 is used as a part of cement than when only cement is used. However, in recent years, affected by the burning method of boiler, collecting

method, quality of pulverized coal, etc., the carbon content in some of fly ash has increased Therefore, fly ash conforming to JIS A 6201 shall be used.

(5) At present, many kinds of products of superplasticizer are on the market, and each of them has its own characteristic.
For instance, there are such products as cause significant slump loss, remarkable retarding action for setting or increase in the bleeding. Therefore, it is better to select superplasticizer from those conforming to the JSCE "QUALITY Standard for Superplasticizer for Concrete", taking into consideration temperature, pumping conditions, type and size of structure, time of form removal, etc.
(Refer to the JSCE "Recommended Practice for Superplasticized Concrete".)

Section 4 Mix Proportion

Article 18 General

The mix proportion of concrete shall be determined so that the water content is as small as possible but lies within the range in which required strength, durability, watertightness, unit weight per volume (for use with artificial light weight aggregate concrete and blast furnace slag aggregate concrete) and suitable workability are assured.

(Commentary)
The concept shown in this article is fundamentally the same as that shown in the JSCE Standard Specifications for Concrete. Although pumpability is a factor of workability, that the segregation of materials is not caused during placing and compacting is at the same time a requirement as to workability. Therefore, it is not desirable to increase indiscriminately the cement content and sand-coarse aggregate ratio or to determine a larger slump, thinking much of pumpability only. To assure the above-mentioned well-balanced workability most economically as well as required qualities of concrete, it is necessary to determine the mix proportion so that the water content is as small as possible.
It must be taken into consideration that the workability of concrete varies depending on the quality of materials, type and shape of structure, placing method, the time from mixing to completion of placing, weather conditions, pumping conditions, etc.

Article 19 Maximum Size of Coarse Aggregate

The maximum size of coarse aggregate shall be determined taking into consideration the minimum dimension of structural member, minimum horizontal clearance between reinforcing bars, etc.

Article 20 Slump

(1) The standard ranges of slumps for concrete are 10 cm or less for prestressed concrete, 12 cm or less for reinforced concrete and plain concrete, and the slump shall be as low as possible but within the range in which suitable operations are assured.

(2) When slump more than that described in (1) is adopted in order to increase pumpability, as a rule, superplasticized concrete shall be used. In such a case, the slump shall be determined to have a value within the range suitable for operations, and as a rule shall not be more than 18 cm.

(3) The slump immediately after mixing shall be so determined that an appropriate value is assured after the change during the time from mixing to completion of concrete placing.

(Commentary)

(1) For prestressed concrete generally richmix is used, and pumping is possible without increasing slump. Therefore, the standard range of slump has been decided to be 10 cm or less. For reinforced and plain concrete, the standard range of slump has been decided to be 12 cm or less, taking into consideration the range of design strength generally being adopted. When concrete containing coarse aggregates the maximum size of which is 40, 25 or 20 mm is pumped through a piping having a diameter of 150 mm or less, it is generally said that the minimum slump ensuring stable pumping is 8 cm or so. As to the pumping of concrete slump of which is less than 8 cm, Article 37, paragraph (4) of this Recommended Practice should be referred to.

(2) Even if the strength of concrete has an enough margin, it is not desirable to increase water content in order to increase the fluidity for pumping because a large water-cement ratio may reduce the durability of concrete. Even when the water content is increased while keeping the water-cement ratio constant' increased cement content causes more cracking, so the durability is also influenced. Therefore, in this Recommended Practice, consideration is given so that the water content should not be increased in concrete work by a concrete pump more than that in concrete work by conventional methods. For this it has been decided that the increase of slump can be allowed only in case of using superplasticized concrete. However, even in superplasticized concrete, excessive slump is liable to cause the segregation of concrete and to increase the possibility of clogging. Therefore, the upper limit of slump for superplasticized concrete has been decided to be 18 cm, taking the slump variation into consideration. (Refer to the JSCE "Recommended Practice for Superplasticized Concrete".)

(3) When the pumping distance is 100 m or less, the change in slump is scarcely perceived after pumping is completed. However, when the pumping distance is 150 m or more, the slump decrease of 1 cm or so may be perceived in some cases at the outlet of piping.

Article 21 Air Content of Concrete

(1) The air content of ordinary concrete and blast furnace slag concrete shall be selected to be in a range of 3 to 6 percent of the volume of concrete depending on the maximum size of coarse aggregate and other factors.

(2) The air content of artificial light weight aggregate concrete shall be selected to be in a range of 4 to 7 percent.

(3) The air content immediately after mixing shall be so determined that an appropraite value is assured after the change during the time from mixing to completion of concrete placing.

(Commentary)

(3) The air content of concrete has a tendency to decrease to some extent during supplying and pumping. Although the decrease of air content varies according to the weather conditions, pumping conditions, quality of aggregate, type of admixtures, etc., it decreases generally about 0.5 percent during supplying of about 30 minutes. The decrease of air content due to pumping is scarcely perceived when the pumping distance is 100 m or so. However, when the pumping distance is 150 m or more, the decrease of about 0.5–1.0 percent is often perceived.

Article 22 Cement Content of Concrete

The cement content shall be as a rule determined based on unit water content and water-cement ratio.

(Commentary)

In general, as to the minimum cement content to enable smooth pumping without clogging, the following values are considered to be appropriate.

- 270 kg/m^3 or so when maximum size of coarse aggregate is 40 mm, slump 12 cm, air content 4%, the piping diameter 150 mm and pumping distance about 100 m, except the case where crushed sand is used. (Refer to Fig. 5 of Commentary)
- 300 kg/m^3 or so under the same conditions as above when crushed sand is used. (Refer to Fig. 6 of Commentary)
- 290 kg/m^3 or so when the maximum size of coarse aggregate is 25 mm or 20 mm, slump 8–12 cm, air content 4%, the piping diameter 150 mm or 125 mm and pumping distance about 100 m, except the case where crushed sand is used. (Refer to Fig. 7 of Commentary)
- 305 kg/m^3 or so under the same conditions as above when crushed sand is used. (Refer to Fig. 8 of commentary)

In these cases, pozzolan added separately to cement may be regarded as a part of cement.

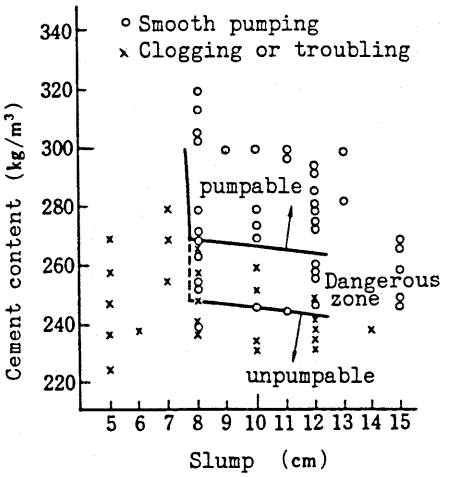
Although the cement content is as a rule determined based on the relationship between water-cement ratio and water content, the examination for pumpability is required when the cement content becomes less than the above value and high strength is not necessary. For particulars, refer to Article 37 "Pumping of Special Concrete", paragraph (4) on poor-mix concrete in this Recommended Practice. Furthermore, care should be taken when the cement content becomes 430 kg/m^3 or more, because it is said that viscosity increases to reduce pumpability. For particulars, refer to Article 37, paragraph (2) on rich-mix concrete in the Recommended Practice.

Article 23 Sand-Coarse Aggregate Ratio of Concrete

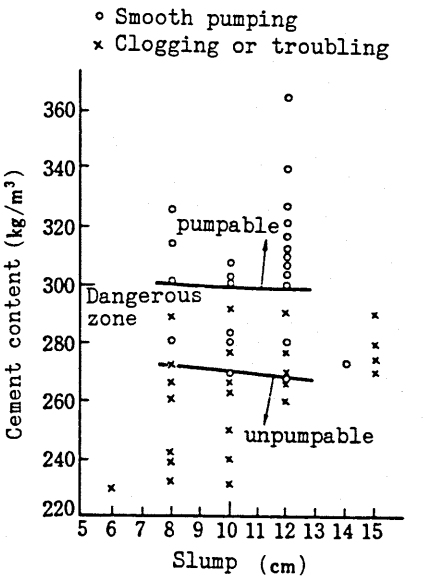
Sand-Coarse aggregate Ratio of concrete shall be so selected that the water content is minimum as far as the required workability is assured.

There is an appropriate sand-coarse aggregate ratio to minimize the water content as far as the required workability is assured, and sand-coarse aggregate ratio is required to be within an appropriate range from the viewpoint of pumping. The decision of sand-coarse aggregate ratio may be done in accordance with the commentary on sand-coarse aggregate ratio in the JSCE Standard Specifications for Concrete.

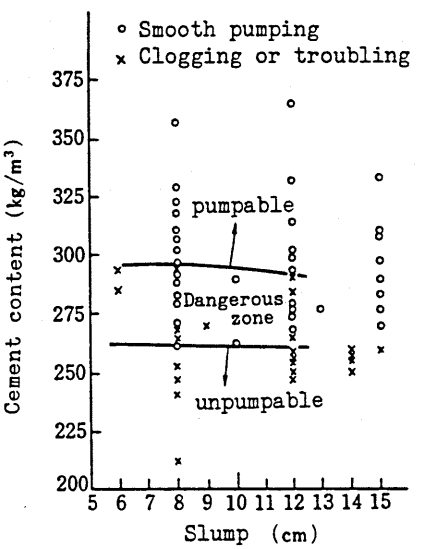
In general, if the sand-coarse aggregate ratio is lowered, the segregation of concrete is liable



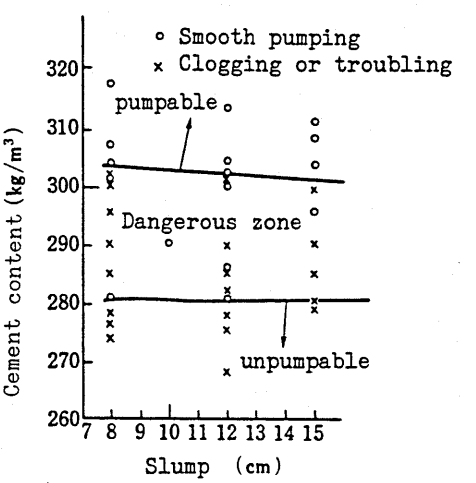
Commentary Fig. 5 Relationship between slump and cement content of natural sand concrete (Maximum size of coarse aggregate is 40mm)



Commentary Fig. 6 Relationship between slump and cement content of crushed sand concrete (Maximum size of coarse aggregate is 40mm)

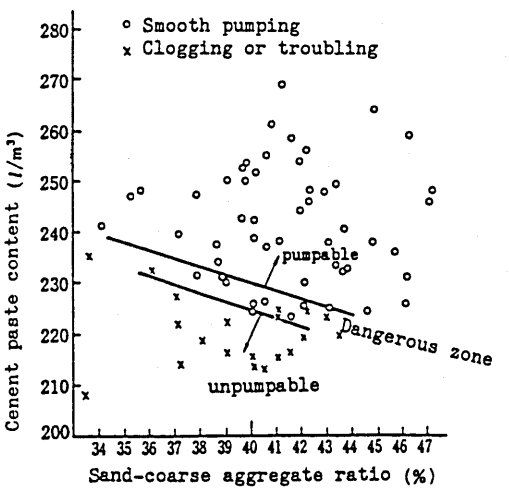


Commentary Fig. 7 Relationship between slump and cement content of natural sand concrete (Maximum size of coarse aggregate is 20,25mm)

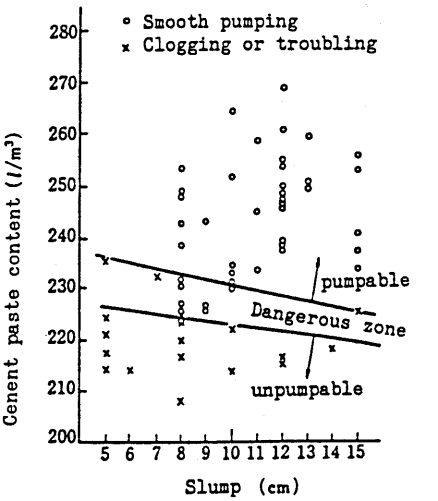


Commentary Fig. 8 Relationship between slump and cement content of crushed sand concrete (Maximum size of coarse aggregate is 20,25mm)

to occur during pumping and the possibility of clogging increases. However, too large sand-coarse aggregate ratio increases the water content for obtaining the same slump, and this increase exerts a bad influence on the quality of concrete. Therefore, it is not desirable to increase sand-coarse aggregate ratio excessively. Since the sand-coarse aggregate ratio of concrete is closely related to the maximum size of coarse aggregate, type, grain size and shape of aggregate, cement content and slump, it is necessary to select the sand-coarse aggregate ratio so that the water content is minimum, taking the balance of these into consideration. Examples of the relationship among these are shown in Fig. 9 and 10 of Commentary.



Commentary Fig. 9 Relationship between sand-coarse aggregate ratio and cement paste content of natural sand concrete (Maximum size of coarse aggregate is 40mm)



Commentary Fig. 10 Relationship between slump and cement paste content of natural sand concrete (Maximum size of coarse aggregate is 40mm)

CHAPTER 4 MANUFACTURE AND SUPPLYING OF CONCRETE

Section 5 Manufacture of Concrete

Action 24 Ready-mixed Concrete

For the use of ready-mixed concrete JIS A 5308 shall be followed.

Article 25 Concrete Manufactured at Site Plant

The manufacture of concrete at a site plant shall be in accordance with the JSCE Standard Specifications for Concrete.

Section 6 Supplying of Concrete

Article 26 Supplying Plan of Concrete

The supplying plan of concrete shall be established in advance so that the continuous placing of concrete is possible.

(Commentary)
The supplying plan of concrete shall be established in advance so that the placing of concrete can be carried out at a planned speed and continuously. In the supplying plan referred to here, the supplying plan of concrete is indicated on the basis of the type and quality (such as strength and slump) of concrete, supply quantity per hour and per day, starting time of supply and scheduled ending time, time for supplying concrete up to site, unloading place, number of pumps to be used and their arrangement, scheduled working time of each pump and the other remarkable matters.
Further, the persons in charge of manufacturing concrete shall be acquainted with the contents.

Article 27 Supplying of Concrete

(1) The persons in charge of work at site shall closely keep contact with the persons in charge of manufacture so that concrete can be supplied without fail in accordance with the supplying plan.

(2) When the placing operation of concrete must be interrupted temporarily or stopped due to trouble of concrete pump, clogging, rainfall and for other unexpected reason, the persons in charge at site shall immediately communicate with the persons in charge of manufacturing concrete to stop or interrupt the manufacture of concrete.

(3) Significantly segregated concrete or concrete with lowered workability shall not be supplied to the hopper of concrete pump.

(4) Materials other than mixed concrete shall not be supplied to the hopper of concrete pump.

(Commentary)

(3) If significantly segregated concrete or concrete with remarkable slump loss due to the lapse of time after mixing is pumped as it is, the clogging of concrete pump or piping is liable to be caused. Therefore, as a rule, the supplying of such concrete to the hopper of concrete pump has been forbidden. In this case, concrete which can ensure workability by re-mixing or mixing with the other sound concrete may be used, provided that no occurrence of degradation is confirmed. When a super plasticizer is used unavoidably, the approval of responsible engineer shall be obtained. Since abnormal concrete can be checked by visual inspection when concrete is discharged from the shoot of concrete mixer truck, the clogging of concrete pump due to the above causes can be prevented.

CHAPTER 5 PUMPING OF CONCRETE

Section 7 Piping Work

Article 28 Selection of Piping Materials

(1) The pipes used for feeding concrete shall have required strength to meet the pumping conditions, and shall be free from defects such as deformation, holes,

unevenness, etc. and no adhesion of concrete shall occur inside the pipe.

(2) The joints or fittings used for feeding pipes shall have enough strength, and the suitability for quick piping work.

Article 29 Securing Pipes

(1) The horizontal piping shall be secured by supporting stands, and shall not be directly supported on the formwork, reinforcement bars, etc.

(2) The vertical piping shall be firmly secured at the lowest part, and at an intermediate part shall be supported with a suitable spacing so that the horizontal movement is restrained.

(Commentary)

(1) Since in addition to the action of the dead load of pipe and weight of concrete, vibration and swinging occurs during pumping on the horizontal piping, direct installation of the horizontal piping on the reinforcement bars or direct supporting on the form-work disturbs the arrangement of bars and cover. Therefore, the horizontal piping should be preferably installed on supporting stands or scaffold board or the like, and be supported using rope, chain, etc. to restrain vibration and swinging. At this time, sufficient care should be taken to the fixing place so that vibration and swinging during pumping does not exert a harmful influence on the formwork or concrete which has already been placed.

(2) The lowest part of vertical piping receives not only the action of total weight of piping and concrete but also the influence of the vibration and swinging of horizontal pipe connected to the upper and lower part of the vertical piping. Therefore, great importance must be placed on the supporting method for the bent pipe at the lowest part of vertical piping, where the load in the vertical direction should be wholly supported, and this part should be secured thoroughly to a surrounding strong structure by a chain, etc. so as not to be moved by the horizontal force.

Section 8 Confirmation Prior to Pumping

Article 30 Confirmation of Pumping Plan and Working Organization

(1) All the concerned persons of work shall be fully informed of the contents of pumping plan so that the pumping work can be safely carried out in accordance with the pumping plan.

(2) Before starting the work, the working organization for pumping work shall be confirmed and the tasks assigned to each of the concerned persons of work shall be made clear.

Article 31 Confirmation of Concrete Pump and Piping

(1) The concrete pump shall be properly maintained and inspected, and its performance shall be confirmed prior to pumping.

(2) The concrete pump shall be installed horizontally and securely. Further, the installation place of concrete pump shall be selected taking into consideration that the

access of concrete mixer truck can be safely and easily achieved, and the concrete can be continuously supplied.

(3) The piping shall be confirmed that the position, fixing method, supporting method, protection method, etc. are appropriate.

(4) The piping shall be confirmed that the connection parts are firmly tightened and free from leakage.

Section 9 Pumping Operation

Article 32 Pumping Preparation

Prior to start of pumping concrete, the function of each part of machineries and the indications of measuring instruments shall be checked. The pumping operation shall be preceded by a warming-up operation.

Article 33 Pumping Operation

(1) The operator of concrete pump shall attend, as a rule, to the concrete pump during pumping operation.

(2) Prior to start of pumping operation, preceding mortar shall be pumped for the purpose of keeping lubrication of internal surface of concrete pump, piping and the like.

(3) Subsequent to the preceding mortar, concrete shall be supplied to the hopper, and once starting the pumping operation the concrete pump shall be operated at a low discharge rate to check for the function of each part, before the discharge rate should be gradually increased.

(4) Since the pumping load changes in response to the variation in concrete quality and condition at the end of piping, the indication of instruments shall be always checked, and it should be kept in mind of persons in charge that the discharge rate of concrete pump must be decreased instantaneously to a low rate at the time of abnormality.

(5) The pumping operation shall be carried out continuously in accordance with the pumping plan, and shall not be interrupted as a rule. If interruption over long time is unavoidable due to the reset of piping, unexpected accident, etc., the operation shall conform to the Article 34.

(Commentary)

(1) The pumping load of concrete pump changes considerably in response to the quality variation of concrete supplied to the hopper of concrete pump and the difference of condition at the end of piping, etc. As a result, occasionally nearly clogged condition may occur and forcible pumping in such case is liable to cause perfect clogging. Therefore, if any nearly clogged condition has been perceived, measures to prevent clogging must be taken by reducing the discharge quantity or carrying out the reverse operation. Since these operations must be conducted quickly, it has been decided that the operator of concrete pump shall attend, as a rule, to the concrete pump during pumping operation. In recent years, the improvement in performance of concrete pump has advanced, and such a machinery as the control of pumping speed and changeover

of normal or reverse rotation can be peformed by the remote control while watching placing work at the end of piping has also appeared. Even when these machineries are used, it is desirable that the operator should attend to the neighborhood of the concrete pump, taking it into consideration that the pumping conditions of concrete are chiefly determined by the operation of concrete pump, and the nearly clogged condition can be wholly judged by the indication of instruments on the concrete pump. Even when the remote operation is unavoidably performed, the operator shall constantly pay attention to the indication on the control board, and always grasp the conditions in which the concrete pump is operating.

(2) Before starting the pumping of concrete, it is necessary to pump water, cement paste or mortar so as to form a thin layer of paste or mortar on the inside surface of concrete piping, and to improve the lubricity at the time of pumping. If the pumping of preceding mortar is omitted, as concrete moves inside the piping the paste part and mortar part in concrete gradually decreases due to adherence to the inside surface of piping and squeeze into the voids of connecting parts, and the friction between the inside surface of piping and concrete may become large, so that clogging is liable to occur. Water and preceding mortar must be adhered so as to form lubricating film all over the inside surface of piping. In the case of rising pipe, since water and mortar flows filling up inside the piping, the above condition is satisfied. However, in the case of horizontal piping or descending piping, mortar flows in contact with only the lower side of the inside surface of piping, and this is not preferable.

In this case, water is filled inside piping using packing such as clearner balls, and then mortar is pumped, so that mortar is fully filled up inside the piping. This method is also effective to prevent the degradation of quality of concrete due to mixing of water into mortar.

Article 34 Interruption of Pumping

(1) If the pumping is interrupted, the time to resume the operation shall be determined as soon as possible, and persons concerned with related work shall be informed of that time.

(2) If interruption occurs over long time, interval pumping shall be performed to prevent clogging.

(3) If it is anticipated that the pumping operation is interrupted for a long time and the possibility of clogging is high, concrete in the piping shall be discharged. In this case, the discharge shall be carried out in such a manner as not to disturb concrete already placed and arrangement of bars, while safety shall be sufficiently assured.

(Commentary)

(2) If the interruption time extends more than about 10 minutes, interval pumping shall be performed in the midway of interruption by moving concrete by several strokes so as to prevent the clogging in the concrete pump and piping. In this case, if concrete cannot be discharged from the end of piping for some reason or other, it is better to repeat the normal and reverse rotation of concrete pump.

Article 35 Prevention of Clogging and Its Procedure

(1) Before piping is almost clogged, some signs can be found on the instruments and piping, suggesting such a condition. In such a case, the clogging shall be prevented

by decreasing the discharge rate or by shortening the stroke of concrete pumps, or occasionally, by carrying out reverse operation.

(2) When clogging has occurred, flow of concrete shall be recovered by striking lightly the feed pipe in and around the place where clogging occurs with a mallet or the like. When the concrete does not flow yet, the feed pipe suspected shall be demounted, and concrete shall be removed.

(3) The work for recovery of flow shall be performed without delay. When the change in quality of concrete in the feed pipe is anticipated due to prolonged time of recovery work, concrete in the concrete pump and piping shall be discharged and the interior of piping shall be washed away. To resume pumping, the same procedures as the starting of pumping shall be followed.

(Commentary)

(1) Before piping is almost clogged for some reason or other, some signs such as the sudden rise in oil pressure of concrete pump or abnormal vibration of piping can be found.

(2) When clogging has occurred in the midway of piping, the clogged place can be detected by striking the piping with a mallet or the like to listen to the difference of sound.

(3) It is better to take the approximate allowable time for the work for recovery of flow as one hour.

Article 36 Procedure of Stopping Pumping

(1) Prior to completion of pumping, the delivery of concrete shall be adjusted in advance to avoid excess or deficiency in placed concrete.

(2) When the remaining concrete in the piping is finally discharged by the water displacement pumping, preventive measures shall be taken against mixing of water with concrete.

(3) Removal of concrete remaining in the piping and washing operation of feed pipes shall be performed in a specified place after safety of the operation is assured.

(Commentary)

(3) In particular, when air is used, sufficient confirmation of safety is required.

1) Remove the flexible hose at the end of piping without fail, and install a cleaner receiver.
2) Direct the end of piping toward a safe direction, and fasten it to a surrounding firm structure or scaffold, etc. by means of a chain or rope.
3) Discharge the remaining concrete gradually.
4) Since it is possible that concrete is scattered when the remaining concrete is finally discharged, take care not to permit persons to come near the end of piping.
5) When clogging has occurred during squeezing of concrete using air, first vent the air in the piping, and then carry out the removal of feed pipe or the discharge of concrete.
6) If necessary, install in advance a receiver (receiving pan, etc.) for receiving discharged concrete.

Section 10 Pumping Requiring Special Consideration

Article 37 Pumping of Special Concrete

(1) The artificial light weight aggregate concrete shall be superplasticized with a superplasticizer when it is pumped by a concrete pump.

(2) When high-strength concrete and rich-mix concrete is pumped, the diameter of pipe shall be larger than that in ordinary cases, and an appropriate type of concrete pump shall be selected.

(3) When large grain coarse aggregate concrete is pumped, the diameter of pipe shall be appropriate to the maximum size of coarse aggregate, and proper type of concrete pump shall be selected.

(4) When low-slump concrete and poor-mix concrete is pumped, the diameter of pipe shall be sufficiently large, and appropriate piping layout plan worked out and proper type of concrete pumps selected.

(5) When special concrete such as steel fiber reinforced concrete etc. is pumped, trial pumping shall be performed, if necessary.

(Commentary)

The article 37 in this Recommended Practice describes the pumping of special concrete, and the Article 38 describes the pumping under special conditions. In addition, in case that the above two difficult conditions are combined, it is anticipated that the pumping condition will become further severe, and, if there is no reliable data, it is desirable to carry out the trial pumping to assure the pumpability and the quality of concrete.

(1) Since the artificial light weight aggregate absorbs water under pressure during pumping of concrete and this may cause the clogging of concrete in the piping. Therefore, in order to reduce the absorption as much as possible, pre-wetting of aggregate 16% or more for the artificial light weight fine aggregate and 25% or more for the artificial light weight coarse aggregate should be made at the time of mixing. When the artificial light weight aggregate concrete is pumped, concrete shall be, as a rule, superplasticized and slump shall be 18 cm or less.

(2) The high-strength concrete to which superplasticizer is added, and the rich-mix concrete having cement content of 350 kg/m^3 or more have a tendency to increase the pressure drop in the piping as compared with the ordinary concrete because they have a high viscosity, and in some cases, the discharge quantity is decreased up to as much as 70 percent.

(3) When concrete mixed with large grain coarse aggregates having the maximum size not less than 50 mm is pumped, there is the possibility of clogging at the parts of bent pipe, tapered pipe and Y-shaped pipe. Therefore, it is recommended to use pipes of diameter approximately 3 times or more larger than the maximum size of coarse aggregate.

(4) The low-slump concrete having the slump of approximately 8 cm or less has low water content and the pressure loss in the piping becomes large, and accordingly the pumping is difficult. Further, the poor-mix concrete having cement content of approximately 270 kg/m^3 or less has a little amount of mortar content of 0.3 mm or less in the concrete, and therefore the pumping load increases, and accordingly there is a possibility to cause clogging.

Article 38 Pumping under Special Conditions

(1) Pumping to Elevated Place

a. When pumping is performed to an elevated place, a concrete pump having enough pumping capacity shall be selected since the pumping load becomes high.

b. Since the pressure inside the pipe is high, feed pipes with a thick wall shall be used.

c. A check valve (rotary valve) shall be installed, as a rule, on the piping adjacent to the concrete pump.

d. Since the piping is subject to severe vibration, the piping shall be securely supported.

e. Since the interruption of pumping is liable to cause clogging in the concrete pump or at a lower part of piping, interruption shall be avoided as far as possible.

(2) Pumping to Low Place

When pumping is performed to a low place with a high differential head, the stream-down velocity of concrete becomes so high that material segregation of concrete is liable to be caused. Therefore, some means to control the stream-down velocity shall be contrived.

(3) Long-Distance Pumping

a. In the case of long-distance pumping, pumping load is high. Therefore, a concrete pump having enough pumping capacity shall be selected.

b. Since the pressure inside the pipe is high, feed pipes with a thick wall shall be used.

c. Since the piping is subject to severe vibration, the piping shall be securely supported.

d. Since the concrete stays for long time in the piping, mix proportion shall be of less bleeding.

e. Mix proportion shall be determined taking into consideration the change in quality of concrete during the travel in the piping. Piping and pumping conditions shall be selected so that the change in quality of concrete is minimized.

f. In the case of long-distance pumping, interruption of pumping shall be avoided as a rule.

g. Taking into consideration that a great mass of concrete remains in the piping after completion of pumping, the treatment of the piping shall be planned in advance.

(4) Underwater Concreting

a. Mix proportions shall be decided in accordance with the JSCE Standard Specifications for Concrete to minimize the segregation of materials during movement of concrete in water.

b. In underwater concreting, concrete is placed in a deep place and stream-down velocity of concrete is high and material segregation of concrete is liable to occur. Therefore, to prevent the segregation, some means to control the stream-down velocity shall be contrived.

c. To prevent material segregation of concrete due to the settlement in water during the travel of concrete in the piping, some means to avoid the direct

contact of concrete with water at the beginning of placing shall be contrived.

d. During placing of concrete, concrete shall be continuously supplied and pumped.

(5) Pumping in Hot Whether

a. When it is feared that loss in slump may occur, piping shall be covered to prevent it from being subject to the direct sunshine.

b. Since the interruption of pumping is liable to cause clogging, continuous pumping as far as possible shall be planned.

(6) Pumping in Cold Whether

a. In the case of pumping in a cold whether, care must be taken to prevent concrete in the piping from freezing.

b. Since the interruption of pumping is liable to cause freezing, continuous pumping as far as possible shall be planned.

c. After completion of pumping, washing shall be carried out not to allow water to remain in the piping.

(Commentary)

(1) (c) When a rising piping is installed adjacent to the concrete pump, the pressure due to the dead load of concrete always acts on the outlet of concrete pump when the pumping is stopped. Accordingly, when the pumping is interrupted, the backward flow of concrete or dewatering segregation tends to occur in the neighborhood of this rising pipe, and clogging is liable to occur. As a countermeasure, it is better to provide a horizontal piping having the length of about 20% of the height of rising pipe directly before it or to install a check valve on the piping adjacent to the outlet of concrete pump so that the check valve can be closed when the concrete pump is stopped. When pumping is performed to an elevated place, it is necessary to use such a check valve as a rotary valve, which is excellent in water tightness.

(e) when a concrete pump is started again after unavoidable interruption of pumping, it is better to perform reverse operation of 2 to 3 times of piston stroke to return concrete which is about to cause dewatering segregation in the check valve or concrete pump to the hopper of concrete pump, and then to perform mixing fully prior to pumping.

(2) When pumping is performed to a lower place than the concrete pump, concrete in the descending piping falls by gravity to cause the segregation of concrete, and clogging may be caused if the concrete accumulates at the connecting part with the lower horizontal piping. Therefore, it is better to select the pumping condition under which the discharge of concrete exceeds the falling velocity of concrete in the descending piping.

(3) In this Recommended Practice, the long-distance pumping is used for the case in which horizontal pumping is performed to the distance more than 300 m. Since the pumping in the case of long-distance pumping is more difficult than that in the ordinary case, it is preferable to use the superplasticized concrete in order to reduce the pumping resistance. However, too large slump exert a bad influence on the pumping and the quality of concrete, and slump should be preferably limited to 18 cm or so.

(a), (b) In the case of long-distance pumping, pressure applied to the concrete pump

and piping becomes high as in the case of pumping to elevated places, and therefore, when selecting a concrete pump, the kind or type having sufficient margin in its pumping capacity shall be selected.

During pumping, the pressure in the piping becomes high, and accordingly, for the piping up to 300 m in length L(m), from the pump it is necessary to use a thick pipe enough to endure the pressure.

(d) In the case of long-distance pumping, since the concrete stays for long time in the piping, causing bleeding water to accumulate on the upper part of horizontal piping, when the pumping is started again, water is pumped first and there is a possibility to cause the segregation and then clogging of concrete. Accordingly, mix proportion of less bleeding shall be selected.

(e) The slump and air content of concrete is generally decreased during pumping. In particular, when the pumping distance is 150 m or more, loss in slump of about 1 cm and decrease in air content of about 1.0% occurs during pumping.

(4) (c) When pumping is started, an appropriate material (for example, cylindrical sponge for cleaning of piping, etc.) to separate water from concrete shall be selected and used in order to prevent material segregation of concrete due to the contact of concrete with water in the piping or the settlement in water during the travel of concrete in the piping. Further, the placing of concrete shall be carried out inserting the end of piping to the depth of about 30–100 cm or more from the surface of concrete. In this case, care should be taken not to disturb concrete under water by vibration of pipe end caused by the discharge pressure.

(5) (a) When at higher atmospheric temperature the piping is exposed to the direct sunshine, the temperature of piping becomes as high as 50–60°C, and the temperature of concrete in the piping also rises, and thus causing loss in slump which may result in the difficulty of pumping. Therefore, the following countermeasures must be taken to prevent the temperature of concrete in the piping from exceeding 30°C.

1) To spray water on the piping
2) To cover the piping with a mat, etc.
3) To coat the piping with the silver paint.

In particular, care must be taken for the long-distance pumping liable to cause the slump loss, and also for pumping of low-slump concrete or superplasticized concrete.

(6) (a) At lower atmospheric temperature the piping is cooled and the quality of concrete may be subject to a harmful influence. In such a case, countermeasures such as covering the piping with insulation should be taken to prevent cooling, where necessary.

(c) If in a cold environment water remains in the piping after pumping, it will freeze and interrupt the subsequent pumping.

Therefore, the cleaning of feed pipes should be carried out taking care to discharge water completely after cleaning.

CHAPTER 6 PLACING OF CONCRETE

Article 39 Placing

(1) The quantity of concrete to be pumped shall be decided taking into consideration the capability of placing, kind of structure, configuration, supplying capacity of concrete, compacting capability, formwork strength of timbering, weather

conditions, etc.

(2) During placing concrete, the end of piping shall be securely held, and care must be taken so that concrete does not splash such places as reinforcing bars, formwork, embedded articles, etc.

(3) The pumping operation shall be stopped when moving the feed pipe end, and care must be taken not to drop concrete, aggregates, etc. during the movement.

(4) When placing concrete, bleeding water shall be removed as far as possible.

(5) When the concrete must be placed too thick and placed in 2 layers or more, concrete shall be placed within the time range in which cold joints between layers does not occur.

Article 40 Compaction

(1) When complete compaction of concrete is difficult only by interval vibrators, external vibrators shall be used in combination.

(2) Concrete shall be compacted right at the place of the pipe end where concrete is discharged, and internal vibrators shall not be used for transporting concrete laterally.

Article 41 Finishing

Taking into consideration that the placing speed of concrete in the pumping method is generally higher than that of other methods, as a result causing much more bleeding, appropriate finishing time and allocation of persons shall be allowed for in the plan.

CHAPTER 7 QUALITY CONTROL AND INSPECTION

Article 42 General

In order to construct concrete structures having specified qualities economically, materials of concrete, mix proportions of concrete, quality of concrete, machinery and equipment, work operations, etc. shall be controlled.

Article 43 Control on Manufacturing Concrete

(1) When the ready-mixed concrete is used, the quality control shall be carried out in accordance with JIS A 5308 "Ready-mixed Concrete," Article 7.5 "Quality Control."

(2) When the concrete is manufactured at a site plant, the quality control shall be performed in accordance with the JSCE Standard Specifications for Concrete, Article 188 "Control of Concrete by Checking Compressive Strength."

Article 44 In-coming Inspection and Tests of Concrete

(1) Immediately after concrete arrives at the work site, the following tests shall be performed.

a. Slump test

b. Air content test
c. Unit weight test for artificial light weight aggregate concrete;

(2) Specimens for the compressive strength test shall be prepared.

(3) The tests shall be performed by the methods specified in JIS A 5308 "Ready-mixed Concrete."

(4) When the test results meet the following requirements, the concrete is judged as accepted.

a. Tolerance for slump or the maximum allowable difference between measured and the specified slump of concrete shall follow Table 2.

b. Tolerance for air content or the maximum allowable difference between measured and the specified air content follow Table 3.

c. Artificial light weight aggregate fresh concrete shall have a unit weight of concrete of the specified value or less with a variation within 5 percent from the average value.

d. The allowable maximum or minimum temperature of concrete shall be determined in advance as agreed by the manufacturer, and the temperature of concrete at the reception shall lie within the range as agreed.

Table 2 Allowable Difference of Slump

Kind of Concrete		Slump (cm)	Allowable Difference (cm)
Nomal Concrete		8–12	±2.5
Superplasticized Concrete	Based Concrete	5–8	±1.5
		8–12	±2.5
	After Superplasticized	8–18	±2.5

Table 3 Allowable Difference of Air Content

Kind of Concrete	Allowable Difference of Air (%)
Normal Concrete	±1
Artificial Light Weight Aggregate Concrete	±1.5

(5) As for the concrete which failed to pass tests, necessary measures shall be taken in accordance with the instructions of the responsible engineer.

Article 45 Control from Beginning of Pumping to Placing

Concrete shall be controlled by visual inspection for the presence of segregation, variation in slump, etc. over the time from the beginning of pumping to the end of placing.

Article 46 Quality Inspection of Concrete

The quality inspection of ready-mixed concrete, shall be carried out in accordance with JIS A 5308, and the quality inspection of concrete manufactured at a site plant shall be in accordance with the JSCE Standard Specifications for Concrete, Article 190 "Quality Inspection of Concrete."