Characteristics required for concrete pumping
泵送混凝土的特性要求

Concrete is a material run through pumping pipes, the quality and mixture ratio of
混凝土作为输送泵的工作对象，其质量和配合比直接影响着
concrete directly affects pumping efficiency and pumping characteristics. The
输送泵的工作效率和泵送性能。
operator of the machine should understand the requirements for the pumped concrete,
故混凝土泵的使用者必须了解泵送混凝土的要求，
which include quality of constituent parts, mixture ratio and concrete producing
包括对混凝土组成材料的品质、配合比及
equipment, etc.
制备质量要求等。

It is wrong to think that concrete with any mixture ratio can be pumped, or tested
不要误认为凡是工地上使用的任何配合比的混凝土都是可以泵送的，更不能
with any concrete formula, because these may result in faults or blockage and lead to
用随意得到的混凝土配方在泵机上作输送试验，否则因此而产生的故障和堵塞
expensive repair.
现象将使人们对泵产生恶感，并造成很大损失。

Pumped concrete should comply with the requirements of the criteria JGJ/T 10-95 “Working Technical Regulation for Concrete Pumping”.
泵送混凝土必须符合“JGJ/T10-95”《混凝土泵送施工技术规程》的要求。

1 Concrete characteristics
混凝土的性质

According to different application, concrete is composed of cement, water, fine
混凝土是根据不同的用途将水泥、水、细骨料（砂）、
aggregate (sand), coarse aggregate (stone), etc. with proper ratio. Its characteristics
粗骨料（石）等按恰当比例加以搅拌而成，
are different in different phases:
其性质可氛围两个方面来讲：

a. Hardened concrete.
尚未凝固的混凝土

b. Unset concrete.
已经凝固的混凝土

1.1 Characteristics of hardened concrete
凝固混凝土的性质

The characteristics of hardened concrete mainly include strength, durability, solidity
凝固混凝土的性质主要包括强度、耐久性、体积稳定性及抗渗性等，而影
and anti-penetration, etc. The main factors affecting the characteristics are
响这些特性的主要因素包括组成材料、制备方法、养护过程等。
ingredients, production method, and maintenance process, etc. Anti-compression
目前通常采用混凝土的抗压
strength is a factor to evaluate concrete quality. In normal conditions, the
强度来评定混凝土的质量。一般认为，
improvement of concrete strength leads to that of other characteristics, but there are
混凝土强度的改善也会改善其它性能，但也有一些重要的例外。
exceptions, e.g. the higher the volume of cement will increase anti-compression
例如：水泥含量的增加会提高抗压强度，

strength, but increase concrete contraction and slow-change.
但相反同样会增加收缩和徐变量。

1.2 The characteristics of unset concrete
未凝固混凝土（生拌混凝土）的性质
The characteristics of unset concrete are very important for they not only directly effect the
未凝固混凝土的性质是很重要的，因为它不但直接
characteristics of hardened concrete but also effect the construction quality and cost. The
影响硬化后混凝土的性质，同时也影响工程的施工质量和工程成本。
characteristics of unset concrete mainly include density, fluidity, condensation, plasticity, etc.
未凝固混凝土的性质主要包括稠度、流动性、可聚性、可修饰性等。

To obtain the highest quality for hardened concrete,
对于指定的工程，为了使硬化混凝土具有满意的质量，
the mixed concrete should satisfy the following requirements：
生拌混凝土必须满足下列要求：
a. Easy to be mixed and pumped.
必须易于拌合及输送（易于泵送）
b. Homogeneity.
均匀性
c. Fluidity and easy to fill the set mold.
必须具有流动性，能充分填满所设计的模型
d. Enough density.
必须具有充分密实的能力，而不必施加过多的能量
e. No concrete disintegration during pumping, placing and hardening.
输送、浇灌及凝固过程中，不应离析
f. Suitable plasticity.
必须可以适当地修饰加工。
The above mentioned are concrete working characteristics, it should be noted that
以上特殊性质统称为混凝土的工作性，应强调的是
there are contradictions between the long-term requirements of hardened concrete
凝固混凝土的长期要求与未凝固混凝土的工作要求
and the working requirements of unset concrete.
这两方面是相互矛盾的。
It is important for the designer to keep close contact with the operators to ensure easy
需设计人员与施工人员的密切配合，在满足凝固混凝土的特殊要求的同时，
pumping while satisfying long-term requirements of hardened concrete.
尽可能地提高泵送混凝土的工作性，要求适用泵送作业。
1.3 Basic requirements for pumped concrete
泵送混凝土的基本要求
Proper concrete mixture ratio is the decisive factor for smooth & economic
合适的混凝土配合比，是泵送作业顺利而又经济的
pumping work. Concrete mixture ratio includes: aggregate grade, cement
决定因素。混凝土混合比包括：骨料级配、水泥
content and concrete density. These three factors interact with each other, e.g.
含量、混凝土的稠度三大要素。这三大要素相互交叉起作用。比如：
fine aggregate or small content of cement will lead to difficult pumping, but an
当细骨料或水泥含量小而无法泵送时，可选取
ideal aggregate grade, high sand percentage and more water content can improve
较理想的骨料级配，提高含沙率，多加水等方法来提高
the pumping effect. In case of improper aggregate grade, lower sand percentage

可泵性；当骨料级配不当，含沙量过低，
or too much crushed grain, pumping effect can partly be improved by adding
或片状碎石过多时，可增加些 2.5~0.5CM 的卵石，改变粗骨料级配，
some 2.5----0.5mm pebbles, more cement or water.
也可以用多加水泥或水的方法，部分的改善其可泵性。

1.4 Concrete density（slump）
混凝土的稠度（坍落度）
Many factors can affect concrete density, such as water/cement ratio, aggregate grade,
混凝土的稠度受许多因素的影响：混凝土的水灰比，骨料级配
characteristics, time, temperature, cement characteristics and additive, etc. Among the
及性质、时间温度及水泥特性以及外加剂等。但主要
above, water/cement ratio is the main factor. The value of concrete density is
的影响因素是混凝土的水灰比。泵送混凝土的稠度
measured in slump, which directly reflects water / cement ratio and pumping
一般采用度量混凝土的坍落度值来确定。坍落度直接反映水灰比的大小及混凝
characteristics.
土的泵送性能。

1.4.1 Relation of slump and pumping pressure
坍落度与泵送压力的关系
Value of concrete slump reflects its fluidity. The pumping resistance decreases along
混凝土坍落度的大小反映其流动性能好坏，因此混凝土的输送阻力随着
with the increase of the slump. In other words, the smaller the slump, the greater the
坍落度的增加而减小。换言之，坍落度越小，
pumping pressure. The trend is especially obvious when the slump is below 15 cm.
泵送压力越大，尤其是在坍落度值在 15CM 以下时，这种变化越为明显。

Relation between slump and pumping pressure
坍落度与泵送压力的关系
1.4.2 Relation of pumping volume efficiency and slump scope
泵送混凝土的坍落度范围及对泵送容积效率的影响
Slump scope for pumping concrete should be 6—23cm, but in application, 8--- 18cm
泵送混凝土的坍落度范围为 6~23CM，但实际应用中一般控制在 8~18CM 范围
In case of long distance and high reach pumping, the slump should be about 15cm.
内，这个范围内可泵送性最好，其吸入效果也最佳。对于长距离，大高度的泵送，一般控制在 15CM 左右。
1.4.3 Correct measures for proper concrete slump
混凝土坍落度的保证措施
a. Correct concrete mixture ratio.
严格控制混凝土的配合比
b. Shorten transportation time before pumping.
尽量缩短混凝土在泵送前的运输时间
c. Concrete uniformity.
保证混凝土的匀质性
d. Rapid hardened concrete should not be used to pump.
采用符合国家标准的水泥，一般不得泵送速凝混凝土
二、 Aggregate grade
骨料级配

1. Fine aggregate
细骨料
①Quality and quantity of the fine aggregate 细骨料的品质和质量
The form of the aggregate is important to the pumping performance of concrete.
细骨料根据来源可氛围河砂、海砂、山砂、人工碎砂。河砂可泵性最好，
Natural aggregates are generally easy to pump. Crushed aggregate with angular
人工砂表面粗糙，砂形不好，
irregular shapes is difficult to pump but the ability to retain water is good.
可泵性较差但其保水性较好。
②The request of the fine aggregate 细骨料的粒度要求
Fine aggregate is divided into three types, small, middle and coarse size. The middle
细骨料可霏微粗砂、中砂、细砂三类，
size is the easiest to pump. When using fine grain, more sand and water will be
其中中砂可泵性最好；使用细砂， 需要增加
needed, at the same time, the wear on pump will be increased. On the other hand, the
混凝土中水泥和水用量，加速泵机磨损；
adoption of coarse aggregate produces concrete sedimentation, which leads to
使用粗砂容易产生离析，导致管道堵塞。
blockage. The middle size aggregate means the fineness modulus between 2.3----3.3.
所谓中砂是指细度摸数为 2.3～3.3 范围内的砂子。
Calculation methods of fineness modulus is as follows：
细度摸数 Mx 计算方法是：

The measuring of A 1 --A 6 is shown in following table.
其中 A 1 --A 6 意义如下表所示：
Sieve holes (mm)
筛孔尺寸 Progr. Sieve Passing (%)
分计筛余 Total Sieve Passing(%)
累计筛余

5	a1	A1= a1
2.5	a2	A2= a1+ a2
1.25	a3	A3= a1+ a2+ a3
0.63	a4	A4= a1+ a2+ a3+ a4
0.315	a5	A5= a1+ a2+ a3+ a4+ a5
0.16	a6	A6= a1+ a2+ a3+ a4+ a5+ a6

Figure below is the grade curve, bold line is the optimal grade line, the area between two dotted lines is the zone of “easily pumpable”.
下图是细骨料最佳级配图，图中粗线为最佳级配线，两条虚线之间区域为适宜泵送区。

Fine aggregate optimal grade
细骨料最佳级配图

Using amount of fine aggregate
细骨料的用量
In concrete pumping, the quantity of fine aggregate is closely relative with void of the
在泵送混凝土中，细骨料的用了量同粗骨料的空隙率有很大关系，
coarse aggregate, the filling of cement mortar into coarse aggregate voids decrease
水泥砂浆必须充满粗骨料的间隙，这样不容易离析。

the concrete sedimentation. If the sand content is too low, not only is more amount of
如果含砂率偏低，空隙要由水泥来填充，这样必须增大水泥的用量，
cement needed to fill the voids, concrete sedimentation occurs easily as well. On the
同样混凝土易泌水和离析；如果含砂率过大，则水泥砂浆的流动性大大降低，
other hand, a high percentage of sand will decrease fluidity of the concrete, but in this
泵送阻力显著增加，故在一定条件下都有个最佳含砂率。在含砂率高的情况下，
case, the effect on concrete pumpability can be counteracted by the increase of
只要水泥用量相应增加，对混凝土的可泵性无显著影响。如果粗骨料级配合理，
cement. If coarse aggregate grade is correct, the bigger the maximum grain diameter
则骨料最大粒径越大，最佳含砂率就越低。
of aggregate is, the lower the optimal sand content is.
一般情况下，混凝土的含砂率可按范围选取（见推荐含砂率表）。
Note： the Min. content of sand should not be lower than 40%, or else the pumping will be difficult.
注意：含砂率最小应不低于 40％d，否则泵送十分困难。
Coarse aggregate 粗骨料
2.2.1 The variety & quality of coarse aggregate
粗骨料的品种和质量
Pebbles, macadam or the mixture of pebble and macadam can be used as aggregate in
泵送混凝土可以采用卵石、碎石或卵石和碎石混合骨料。
concrete pumping. Pebbles are the best for pumping, the mixture of pebble and
卵石骨料混凝土的可泵送性最好，
macadam is next, macadam is the worst.
混合骨料次之，碎石稍差。
Too much chipped macadam will decrease the pumpability, so the content of chipped
碎石中针片状骨料含量过大泵送性能差，一般针片状碎石含量控制在 5%以
aggregate should be limited within 5%. In addition, aggregate such as volcanic stone,
内。另外，孔隙率较大的碎石（如火山石、多孔骨料）泵送性也差，在泵送过
multi-hole aggregate with big void percentage will easily lead to blockage in pumping.
程中，泌水较严重，容易出现堵管现象。
2.2.2 Max. aggregate size of coarse aggregate
粗骨料最大粒径
Max. aggregate size is limited by the Min. diameter of the pumping pipe, according
泵送混凝土的粗骨料最大粒径受输送管路最小口径的限制，
to this rule: Max. diameter of pebble should be less than 1/3 of the pipe diameter; for
卵石最大粒径应小于 1/3 口径；
macadam, the Max. diameter should be less than 1/4 of the pipe diameter, but a small
碎石最大粒径应不小于 1/4 口径，
amount of the aggregate larger than this value is permitted, e.g. the aggregate with
允许有少量超径骨料混入。
60mm diameter can pass through the φ125mm pipe, but the ratio should not be
例如在 125 ㎜直径的输送管中，可以通过少量粒径达 60 ㎜的骨料，
more than 2%, and they should be dispersed. The Max. diameter of coarse aggregate
不过这种超径骨料的比例不得大于 2%，而且它们必须是分散的，
is shown in the following table：
粗骨料最大粒径限制见下表：

Min.diameter of pumping pipe 输送管最小直径	Max. diameter 粗骨料最大直径	
	Pebble 卵石	Macadam 碎石
125	40	30
150	50	40

2.2.3 coarse aggregate grade

粗骨料的颗粒级配

Aggregates with smaller void percentages can be pumped easily and use less cement
泵送混凝土粗骨料级配以最小空隙为原则，较小的空隙才能以较少的水泥
and sand. The pumping characteristics are sensitive to lack coarse aggregate grade
及砂用量获得较好的可泵性。混凝土的可泵性对于粗骨料级配间断或不均 匀
and uneven, especially if pumping over a long reach, the coarse aggregate grade plays
的反应十分敏感，特别是在大高度的长距离泵送时，
an important role, even the increase of amount of cement and water will not improve
粗骨料的级配至关重要，多加水泥和多加水都是无用的，
anything. So, please bear in mind, it is wrong to think that a smaller size of aggregate
因此，不要误认为粗骨料粒径越小越好，
(including fine aggregate and coarse aggregate) will contribute to a good pumping, a
也不要误认为小径骨料越多越好，
proper coarse aggregate grade is the most important.
最重要的是粗骨料的合理级配。

Coarse aggregate grade should comply with the following：
粗骨料的级配应符合下列要求

Standard table of coarse aggregate grade （percentage of sieves passing weight of aggregate with different diameters）
粗骨料料级配标准表（各种骨料粒径范围的骨料通过各标准筛的重量百分比率）

Particle diameter(mm)粒径范围(mm)	Φ Sieve holes in mm 筛孔的名义尺寸（mm）							
	50	40	30	20	10	5	2.5	
40-5	100	100-90		70-35			30-10	5-0
30-5		100	100-90	75-40			35-10	10-0 5-0
25-5			100	100-90	90-60		50-20	10-0 5-0
20-5				100-90	100-90	(80-55)	50-20	10-0 5-0

It should be mentioned that if there is absence of grade, it is recommended that
值得一提的是：粗骨料粒径出现简短级配时，
aggregate with 5—10 diameter or 20—30 mm grain diameter be used as a substitute,
可采用 5～10 粒径骨料，或用 20～30 ㎜粒径的骨料代替，
or increase the sand content properly, which not only reinforces the concrete strength,
同时采用适当极大含砂率的办法，这样不仅能使混凝土的强度提高，同时能
but helps to obtain better pumping as well.
获得更好的泵送性能。

The Following are demonstrations of optimal aggregate grades for different
各种粒径范围粗骨料最佳级配图如下，图中粗实线为最佳级配线，两条虚
particle sizes. The bold line is the optimal graduation line, the area between two
线之间区域为适宜泵送区，粗骨料最佳级配区宜尽可能接近两条虚线之间
dotted lines is suitable pumping area.
范围的中间区域。

Φ Sieve holes 筛孔尺寸
Φ particle=5-20mm 粗骨料 5～20mm

Φ Sieve holes 筛孔尺寸
Φ particle=5-25 粗骨料 5～20mm

Φ Sieve holes 筛孔尺寸
Φ particle=5-31.5mm 粗骨料 5～31.5mm

Φ Sieve holes 筛孔尺寸
Φ particle=5-40 粗骨料 5～40mm

2.2.4 Amount of coarse aggregate
粗骨料用量

The percentage of coarse aggregate in concrete plays an important role to
粗骨料在骨料总量中的比例对混凝土泵的可泵性有很大影响，
pumpability, which shows in the variation of pumping pressure and concrete volume
泵主要表现在泵送压力和混凝土容积效率的变化
efficiency (affects suction ability), but in actual application, if the sand content is
（影响吸入功能），但在实际应用中，只要控制好
controlled well, the amount of coarse aggregate will be controlled.
含砂率，粗骨料用量就得到了控制。

2.3 Cement
水泥

2.3.1 Function of cement during pumping
水泥在泵送过程中的作用

Unset concrete, is a dilute suspension, the pumping pressure is transmitted by liquid
未凝固混凝土，作为一种非常稀释的悬浮体，泵送过程中的泵送压力靠其
phase material. The cement has two functions, one is cementation, i.e, keep the
中的液相物质传递。水泥的作用有两方面：一是胶结作用，使混凝土中的骨料 aggregate in the concrete in suspension, and keep solid materials covered by liquid
始终保持悬浮状况，泵送过程中维持固相物质被液相物质包裹的状态；二是润
ingredients; the other is lubrication, i.e, decrease the friction in mechanical parts,
滑作用，使混凝土同泵的机械部分、输送管道及混凝土内部的摩擦阻力见效而
such as pumping pipe and pump to maintain good flow.
具有良好的流动性。

2.3.2 Effect of different kinds of cement to concrete pumping characteristics
水泥品种对混凝土可泵性的影响

Cement has good ability to hold water, so it is not easy to drain off water during
水泥应具有良好的保水性能，使混凝土在泵送过程中不易泌水。
concrete pumping, but different kinds of cement have varying abilities of water
普通硅酸盐水泥、火山灰水泥的保水性较好，而矿渣水泥的保水性差，用粉煤
retention. Normal silicate cement and pozzolanic cement have good water holding
灰水泥，混凝土流动性好，
characteristics, but blast furnace slag cement can not keep water well, concrete with
因此，采用后两种水泥时，
但早期泌水性较大。powered coal ash cement has good fluidity, but is easy to drain out water in its early
需加大水泥用量，并采用较低的混凝土坍落度，
phase. When using the latter two cements, increase the volume of cement with low
且尽可能地连续泵送，以防止混
slump, and pump as continuously as possible to prevent sedimentation and water drainage.
凝土出现离析和泌水现象。

2.3.3 Cement volume
水泥用量

There is also an optimal value for cement volume. If the cement content is
水泥用量一般也存在一个最佳值。若水泥用量不足，将严重影响泵的吸入

insufficient, it will affect pump suction characteristics, increase the pumping
性能，同时使泵送阻力增加，并且混凝土保水性差，
resistance, lower the ability to hold water, which easily results in water drainage,
容易泌水、离析和发生堵管；
concrete disintegration and blockage, but if the cement content is too large, too much
若水泥用量过大，则会使混凝土粘度过大，
adhesive will cause an increase pumping resistance. In principle, too much cement
增大泵送阻力。但原则上讲，
will not affect pump suction characteristics.
水泥用量过大时不会影响泵的吸入性能。

Cement volume is closely related with different kinds of aggregate. In a comparison
水泥用量与骨料品种的关系：同样粒径级配的卵石和碎石，
of pebbles and macadam with the same particle size, the concrete with macadam
后者的水泥用量较大；人工破碎砂与天然砂，
will use more cement. As for crushed aggregate and natural sand, more concrete is
前者的水泥用量大。对于轻骨料或多孔性骨料，
needed with crushed aggregate. For light aggregate or multi-hole aggregate, which
由于具有高压下吸水、低压下放水的特性，
absorbs water at high pressure and loses water in low pressure, results dry & hard
在泵送时容易使混凝土出现喷浆、干硬和泌水，
concrete and water loss during pumping. The smaller the particle size of aggregate,
因此应适当增加水泥用量。骨料粒径越小，相应的水泥用量应增加， the more cement volume should be used, because the small grain diameter will

increase the total surface which needs more cement to cover. But, a too big aggregate
因为骨料粒径小，其表面积增大，需要包裹的水泥浆增加，

with particle diameters more than 40mm will destroy concrete continuity, making it
但当骨料粒径大于 40 ㎜时，
difficult to cover the aggregate with cement mortar sufficiently, so volume of cement
超径骨料会破坏混凝土的连续性，水泥浆也难以将这些骨料充分包容，
used should not be too small.
故水泥用量不能太少。

The Relation between cement volume and pipe diameter, delivery distance: the longer
水泥用量与输送管口径、输送距离的关系：
the distance is, or the smaller pipe diameter is, the higher the demand for the concrete
输送距离越长，输送管口径越小，则要求混凝土的
fluidity, lubricating characteristics and water keeping characteristics will be, so the
流动性、润滑性、保水性越高，
relevant cement volume should be added. In actual application, the Min. limit of
故应增大水泥用量。一般实际应用中，
cement volume is 320kg/m3.
水泥用量最低限度为 320kg/m3.

2.4 Additive
混凝土外加剂

As described above, the concrete mixture ratio is important to pumping
如前所述，混凝土的配合比是影响泵送性能的关键因素，较严格的骨料级
characteristics. The perfect aggregate grade and high-class cement mean an increase
配，较高的水泥用量意味着泵送混凝土成本的提高，

of costs, but the increase of water / cement ratio and sand content will affect concrete
但提高水灰比和含砂率又会影响混凝土强度。
strength. An Economic and effective method is to use additive to improve concrete
一个比较经济而有效的办法是采用外加剂来改善混凝土的可泵性。
pumping characteristics. There are a lot of varieties of additives, some of them will
外加剂的种类很多，其中能改善混凝土可泵性的外加剂有加气剂、
help to improve pumpability, such as those that air-entraining agent, water-reducing

agent, super plasticizing agent retarder and pumping agent.
减水剂、超塑化剂、缓凝剂及泵送剂。