NO-FINES CONCRETE - ITS PROPERTIES AND APPLICATIONS

by

V. M. Malhotra

Mineral Processing Division,

Mines Branch,

Department of Energy, Mines and Resources,

Ottawa, Canada.

Mines Branch Information Circular IC 313

NO-FINES CONCRETE - ITS PROPERTIES AND APPLICATIONS

by

V. M. Malhotra*

- - -

SYNOPSIS

No-fines concrete consists solely of normal portland cement, water and coarse aggregate. It has been used in Europe and the U.K. since the 1930's for the building of single- and multi-storey dwellings, but had found little acceptance in North America. In recent years, however, due to increased awareness of the need for conservation of non-renewable mineral resources, increased consideration is being given to the use of no-fines concrete in Canada and the U.S.A.

The compressive strength of no-fines concrete is considerably lower than that of conventional portland cement concrete and generally varies between 200-2000 psi (1.4-13.7 MN/m^2). Young's modulus of elasticity is usually between 1.0 x 10^6 to 1.5 x 10^6 psi (0.7 x 10^4 to 1.2 x 10^4 MN/m^2) depending on the strength level of the concrete. The ratio of modulus of rupture to compressive strength expressed as a percentage varies between 10.8 and 31.0 per cent.

*Head, Construction Materials Section, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

The shrinkage of no-fines concrete made with crushed limestone or river gravel, is of the order of 200 x 10^{-6}. This is about half that of conventional concrete.

Investigations at the Mines Branch have indicated that no-fines concrete prisms with no air-entraining agent had poor resistance to freeze-thaw cycling. The prisms incorporating an air-entraining agent were able to withstand up to 274 freeze-thaw cycles compared with 56 for prisms without an air-entraining agent.

The principal advantages claimed for no-fines concrete are economy in materials, higher thermal insulating values, lower shrinkage and lower unit weight. The major disadvantages are its low compressive, flexural, and bond strengths and higher permeability.

The principal applications of no-fines concrete are for load-bearing, cast-in-place external walls of single- and multi-storey housing, small retaining walls and as a damp-proofing sub-base material for concrete floors cast on grade. This type of concrete is also eminently suitable for construction in northern Canada because of its higher thermal insulating property and low cement content.

iii

Direction des mines

Circulaire d'information IC 313

LES PROPRIÉTÉS ET LES APPLICATIONS DU
BÉTON SANS ÉLÉMENTS FINS

par

V. M. Malhotra*

- - -

RÉSUMÉ

Le béton sans éléments fins est uniquement compose de ciment
portland, d'eau et d'agrégat grossier. On a utilisé ce béton en Europe
et au Royaume-Uni depuis les années 1930 pour la construction de logis
à un et à plusieurs étages mais ce béton a eu peu de succès en Amérique
du Nord. Toutefois, depuis quelques années, pour conserver les ressources
minérales non-renouvelables, le Canada et les États-Unis ont porté plus
d'attention à l'utilisation du béton sans éléments fins.

La résistance à la compression du béton sans éléments fins
est inférieure à celle du béton conventionnel de ciment portland et
elle varie générallement entre 200 psi (1.4 MN/m^2) à 2000 psi (13.7 MN/m^2).
Le module d'élasticité de Young est habituellement entre 1.0 x 10^6 à
1.5 x 10^6 psi (0.7 x 10^4 à 1.0 x 10^4 MN/m^2) selon le niveau de résistance
du béton. Le rapport du module de rupture à la résistance à la compression
exprimé en pourcentage varie entre 10.8 et 31.0 poucent.

Le retrait du béton sans éléments fins fait de calcaire broyé
ou de gravier de rivière est de l'ordre de 200 x 10^6. C'est à peu près
la moitié de celui du béton conventionnel.

Les études faites à la Direction des mines ont montré que les
prismes du béton sans éléments fins en l'absence d'agent entraîneur d'air
avaient une pauvre résistance aux recyclages de gel et dégel: Les prismes
ayant l'agent entraîneur d'air avaient résisté à 274 recyclages de gel et
de dégel comparés à 56 pour les prismes en l'absence d'agent entraîneur
d'air.

---

*Chef, Section des matériaux de construction, Division du traitement des
 minéraux, Direction des mines, ministère de l'Énergie, des Mines et des
 Ressources, Ottawa, Canada.

Les principaux avantages du béton sans éléments fins sont les
matériaux économiques, les valeurs plus élevées de l'insolation thermique,
le retrait moins élevé et le poids unitaire plus bas. Les désavantages
majeurs sont sa faible force de compression, de flexion et de liaison
et sa perméabilité plus élevée.

Le béton sans éléments fins est utilisé surtout dans le
soutènement de charge des murs externes coulés sur place pour des logis
à un ou à plusieurs étages, dans de petits murs de soutènement et comme
matériel de fondation d'hydrofugation pour des planchers en béton coulé
à niveau. Ce genre de béton est aussi très convenable pour la construction
dans le nord canadien à cause de sa propriété d'insolation thermique
élevée et sa faible teneur en ciment.

CONTENTS

TABLES

FIGURES

FIGURES (Continued)

INTRODUCTION

No-fines concrete, as the name implies, is concrete from which the fine aggregate fraction has been omitted. The concrete so formed, consisting only of coarse aggregate, cement and water, has large voids uniformly distributed throughout its mass. Many special properties of no-fines concrete are attributed to the presence of these voids (Fig. 1).

The most commonly used coarse aggregate fraction is minus 3/4 in. plus 3/8 in. (minus 19 mm plus 9.5 mm), though satisfactory no-fines concretes have been made with any coarse aggregate grading from which the fine fraction has been removed.

No-fines concrete has usually been used for load-bearing walls of single and multi-storey houses and, in some instances, of high rise buildings. This type of concrete is most economical for large housing developments where repetitive use of formwork is possible for in-situ placement of external walls.

Although no-fines concrete has been used in Europe for the past 30 years, it has only recently gained attention in North America. The emphasis on conservation of non-renewable mineral resources and energy has given further impetus to explore its possible uses.

This information circular traces the development of no-fines concrete in continental Europe and the U.K. and discusses its special properties, applications and limitations. The results of investigations performed at the Mines Branch on freeze-thaw resistance are presented; and possible use of this type of concrete in Northern Canada is briefly discussed.

Fig. 1. A close-up view of no-fines concrete.

DEVELOPMENT OF NO-FINES CONCRETE

Early Developments

The earliest recorded use of no-fines concrete is in the U.K.,
where in 1852 two houses were constructed using coarse gravel and cement.
This was followed by the construction of more houses (1). An editorial in
the 1852 issue of Civil Engineer and Architect's Journal states:

> "On a recent professional visit to East Cowes, Isle of Wight,
> we were much pleased with the economy displayed in the
> construction of two houses now being built on this beautiful
> estate near to Osborne House under the direction of Mr. Langley.
> On the spot is some excellent gravel which has been very advan-
> tageously turned to account by building a pair of cottage villas
> entirely of concrete composed of Francis' Madina cement and
> coarse gravel which has been carefully sifted clean and freed
> from sand and dirt. The walls are carried up, as well as the
> chimneys, by fixing two or three boards vertically and filling
> in the concrete between, about 12 to 14 ins thick, by which
> method, in consequence of the quick setting of the cement, the
> walls are carried up and the boards shifted within three or
> four hours after the wall is built. Even the arches are turned
> with it, and no bricks are used.
>
> We may add that in Sandown Bay in the Isle of Wight, a sea
> groyne of 200 ft in length and about 7 ft in height has been
> built of the same materials at right angles to the shore, for
> the purpose of forming a breakwater in protection of the land
> and that it has achieved its object to the satisfaction of the
> owner of the property, where everything else had been swept
> away. The groyne has now stood twelve months exposed to all
> the violent gales we have had in the channel and it was lately
> inspected by order of Sir John Burgoyne, on the part of the
> Government".

It is strange that following the above development nothing was
heard of no-fines concrete for the next 70 years. It is now claimed (2)
that it was reintroduced into the U.K. in 1923 from Holland, when 50 two-
storey houses were built in Edinburgh, followed a few years later, by 800

or more in Liverpool, Manchester, London, and Willesden. Clinker aggregates were used throughout. In the late 1930's, the Scottish Special Housing Association Limited, established in 1937 to relieve unemployment in Lanarkshire by building houses with the maximum proportion of unskilled labour, adopted it using whinstone aggregate. By 1942, it had completed 901 houses in Lanarkshire, and at Rosyth and Dunfermline (2).

Investigations since 1928 at the British Building Research Station (3) have played an important role in the use and development of no-fines concrete in the U.K. The real impetus for its use came following the Second World War when all forms of building materials were in short supply. As considerably less cement per cubic yard of concrete is used than for conventional concrete, this type of concrete came into widespread use in Germany, Holland, France, Belgium and Russia and to a lesser degree in England (2). Nevertheless, since 1946, a single British firm has built more than 250,000 dwellings in the U.K., and others under large contracts overseas.

Recent Developments

In the early stages of development of no-fines concrete, its use was confined to two-storey houses, but in the 1950's was extended to five-storey dwellings (Fig. 2). According to Short and Kinniburgh (4), in recent years it has been used as the load-bearing material in buildings up to 10 storeys high (Fig. 3). In one project in Stuttgart, Germany, a building consists of six lower storeys of conventional concrete and thirteen upper storeys of no-fines concrete. All those upper walls are load-bearing and the building has no reinforcing frame (5). Studies have also been performed at the Building Research Station, England, on the behaviour of such panels as the infill in reinforced concrete frames (6).

In North America, the use of no-fines concrete has been almost
non-existent and the only documented reference to this type of concrete
appears to be a minor technical note in 1950 by R. Forlani*. This neglect
is perhaps due to the fact that after the Second World War, North America
did not experience the materials shortage to the same degree as did continental
Europe and England. However, studies were undertaken at the U.S. Bureau of
Standards in 1943 and again in 1951 to develop engineering data on no-fines
concrete (7, 8). In one of the studies (7), a special type was investigated,
in which the only aggregate used was a minus 3/8 in. (9.5 mm), plus No. 4
(4.75-mm) fraction of silicious pea gravel together with high early-strength
cement. Fine aggregate was totally eliminated; instead, 20 to 30 per cent
entrained air was achieved by the use of air-entraining agents.

In Canada, the only reported use of the concrete under study was in
1960 in the building of some houses in the Toronto area (9). More recently,
minor amounts were specified for non-structural uses in a Federal building
in Ottawa**. In 1973, the Canadian Standards Association issued a Standard
on it (10).

---

*Proceedings, American Concrete Institute, V. 21, 1950, p. 477.

**Personal Communications from John Bickley, Construction Testing Services
 Ltd., Toronto, Canada; also refer to a report entitled "No-fines Concrete-
 Project 135" 1968, issued by the Construction Testing Services Ltd.
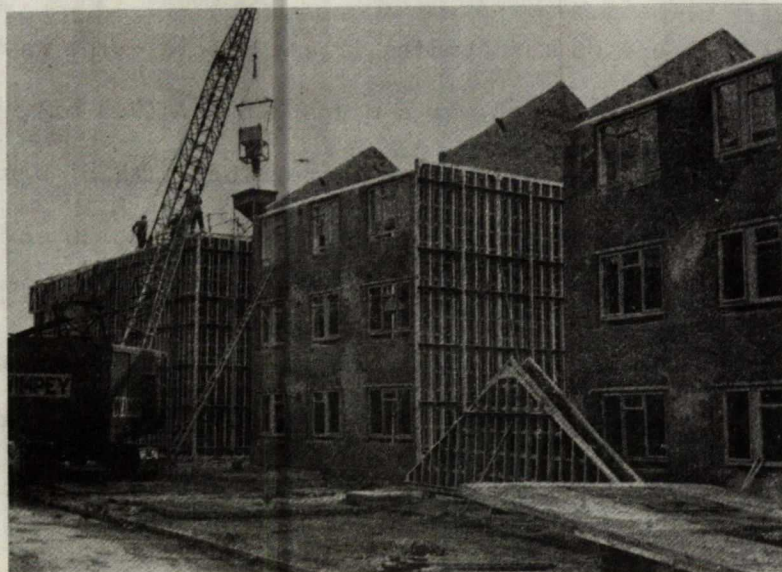
Fig. 2. Three-storey dwellings under construction with no-fines concrete.
From Reference (4).
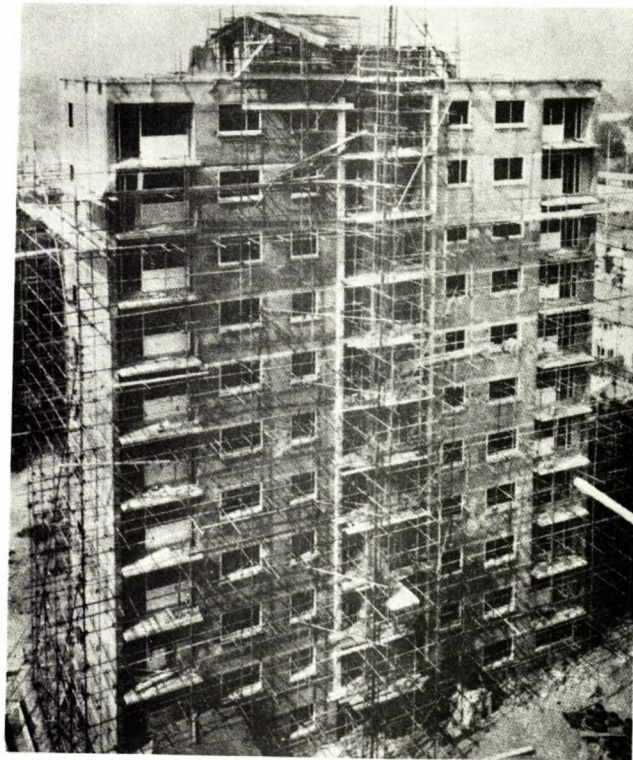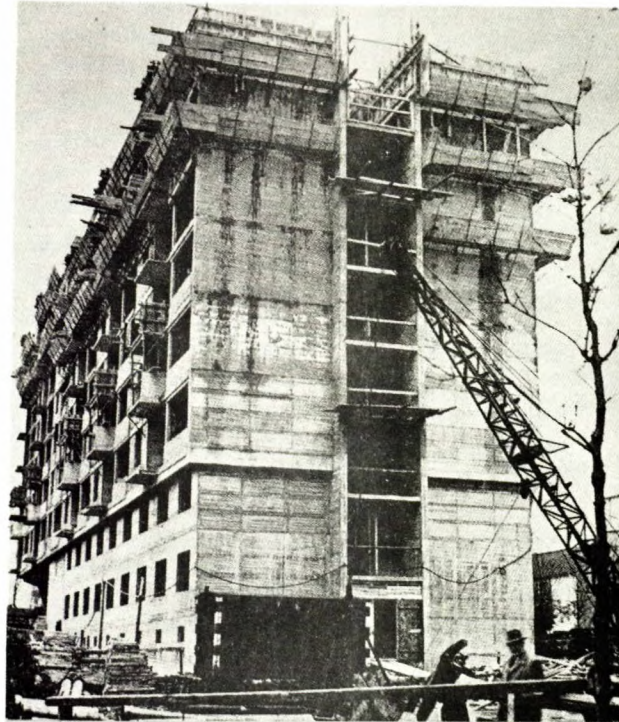
Fig. 3. Multi-storey buildings under construction with no-fines concrete.

Top: At Coventry, England.
Bottom: In Germany with lightweight aggregate.
(From Reference 4).
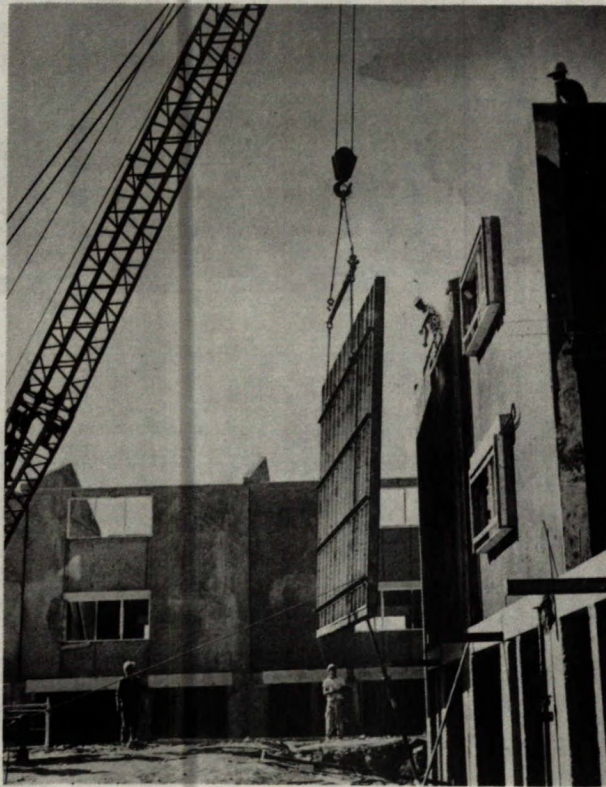
Fig. 4. Houses under construction in the Toronto area
using no-fines concrete.

From Reference (9).

MATERIALS AND MIX PROPORTIONS

Materials

In general, the cement and aggregate for no-fines concrete should satisfy the requirements for conventional concretes. The former are usually made with ordinary portland cement, but the use of rapid-hardening and blast furnace slag cements has also been reported (11).

The aggregate grading limits for no-fines concrete given in Table 1 are different from those for conventional concrete. Although aggregates with a maximum size of 1.5 in. (37.5 mm) have been successfully used, 0.75-in. (19-mm) maximum size is commonly used. Ordinarily, conventional aggregates such as crushed limestone or natural gravel are used, but commercially produced lightweight aggregates from clays or shales are equally suitable. The CSA Standard "A23.4" stipulates that flat, flaky or elongated aggregates shall be limited to 20 per cent and material finer than No. 200 (74 μm) shall not exceed 1 per cent by weight of total aggregate (10).

Admixtures have not normally been used in no-fines concrete practice. However, the use of air-entraining agents for improving the freeze-thaw resistance (12) and calcium chloride for accelerating the setting (13) have been reported.

TABLE 1

Grading Requirements for No-Fines Concrete*

Sieve Size		Total passing each sieve, per cent by weight		
in.	mm	2.0 in. (50.0 mm)	1.0 in. (25.0 mm)	0.5 in. (12.5 mm)
2.0	50.0	100		
1.5	37.5	95-100		
1.0	25.0		100	
0.75	19.0	0-5	95-100	
0.5	12.5			100
0.375	9.5		0-5	95-100
No. 4	4.75			0-5

*From References (10, 11)

Mix Proportions

Unlike conventional concrete in which strength is primarily controlled by the water-cement ratio, the strength of no-fines concrete is dependent both on the water-cement ratio and the unit weight of the concrete.

The water-cement ratio for a satisfactory consistency will vary with each particular source or type of cement. For a given aggregate, there is a very narrow optimum range of water-cement ratio for this type of concrete, and this usually varies between 0.38 and 0.52. Excessive amounts of water yield a paste which is too fluid and which flows off the aggregate particles, reducing cohesion in the upper portion of the specimen or structure and filling voids in the lower part. Too little water results in a paste which does not coat the aggregate particles completely, leading to insufficient adhesion between the particles so that proper compaction cannot be achieved. The quantity of cement paste is considered sufficient when it coats the coarse aggregate with a shining film giving it a metallic gleam. (Fig. 5).
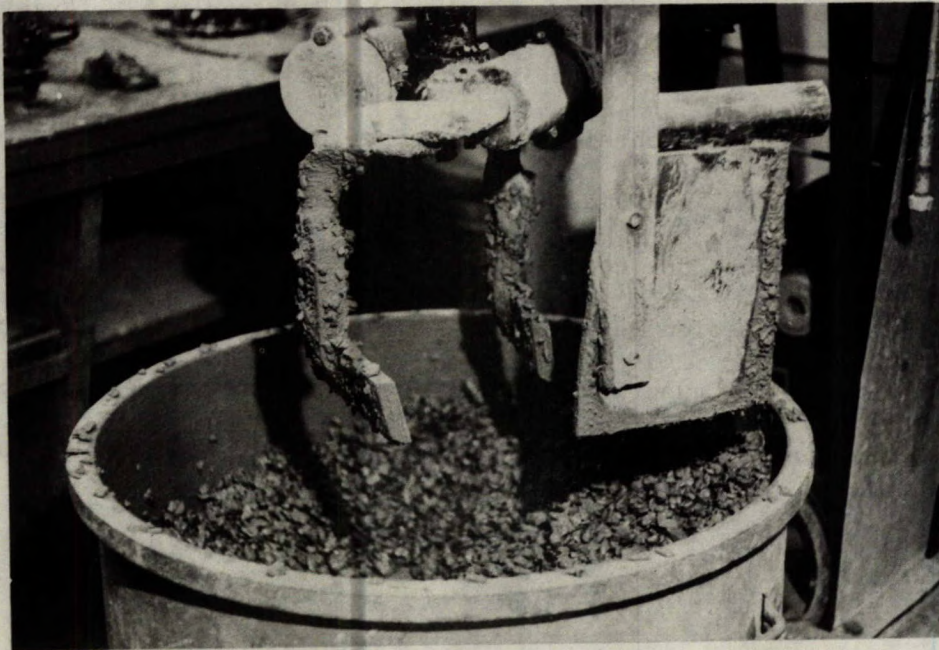
Fig. 5. Freshly mixed no-fines concrete in a counter-current mixer.
From Reference (12).

PROPERTIES IN THE FRESH STATE

Consistency

Unlike conventional concrete, there are no standard methods of measuring consistency of no-fines concrete. The standard slump test or the Kelly-ball test is not applicable because of the very nature of the product. Visual examination to ensure that each particle is evenly coated with a cohesive cement paste appears to be most satisfactory. Some organizations have tried to develop a consistency test in which the concrete is dropped 4.5 ft (1.37 m) into a bucket with holes in the bottom until the bucket is half full. If, within one minute, no cement has come through the holes, consistency is assumed to be satisfactory. Figure 6 shows one such bucket. As mentioned earlier, for satisfactory performance of no-fines concrete it must be ensured that no cement paste drains away from the aggregate particles.

Unit Weight

The unit weight or density is generally 70 per cent that of conventional concrete using similar aggregates. The unit weight is calculated simply as the sum of the rodded bulk density of aggregates in lb/ft^3, plus the cement content in lb/ft^3, plus the water content in lb/ft^3.

For no-fines concretes using conventional aggregates, the density usually varies from 100 to 120 lb/ft^3 (1602 to 1922 kg/m^3). The corresponding value for no-fines concrete made with clinker aggregates is 60 lb/ft^3 (961 kg/m^3).
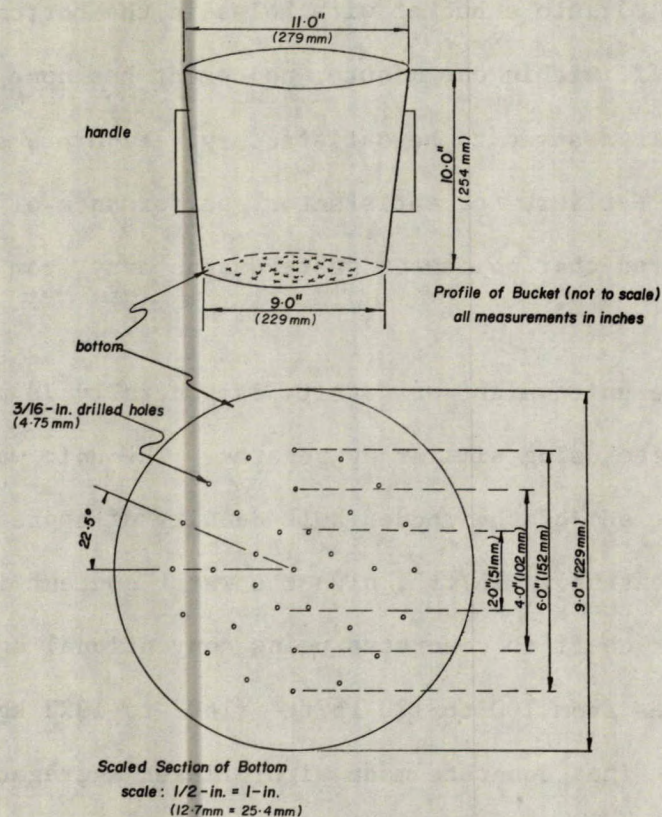
Fig. 6. Heavy duty aluminum bucket for measuring consistency of no-fines concrete.

Top: Looking into the bucket (top diameter 11 in. (229 mm); bottom diameter 9 in. (228.9 mm), height 9.5 in. (241 mm).

Bottom: Size and spacing of holes.

From Reference (12).

Compactability

No-fines concrete is self-packing and can be compacted by gravity alone. The use of mechanical vibration or ramming is generally not recommended. Hand rodding, on the other hand, can be used with advantage to place concrete in the forms. Only light rodding should be used because over-rodding can create local areas of high density. As no-fines concrete does not flow as does conventional concrete, it can form bridges over projecting obstructions. Light hand rodding does help to overcome this problem.

The CSA Standard on no-fines concrete specifies the use of a rammer for casting cylindrical test specimens (Fig. 7). Experience at the Mines Branch indicates that satisfactory cylindrical and prismoidal test specimens can be cast using hand rodding (Fig. 8, 9). The compressive strengths obtained for these specimens are comparable to those obtained by others using a rammer. It is, therefore, suggested that all control test prisms and cylinders should be compacted by hand rodding in accordance with ASTM Standard C31-69 for conventional concrete.
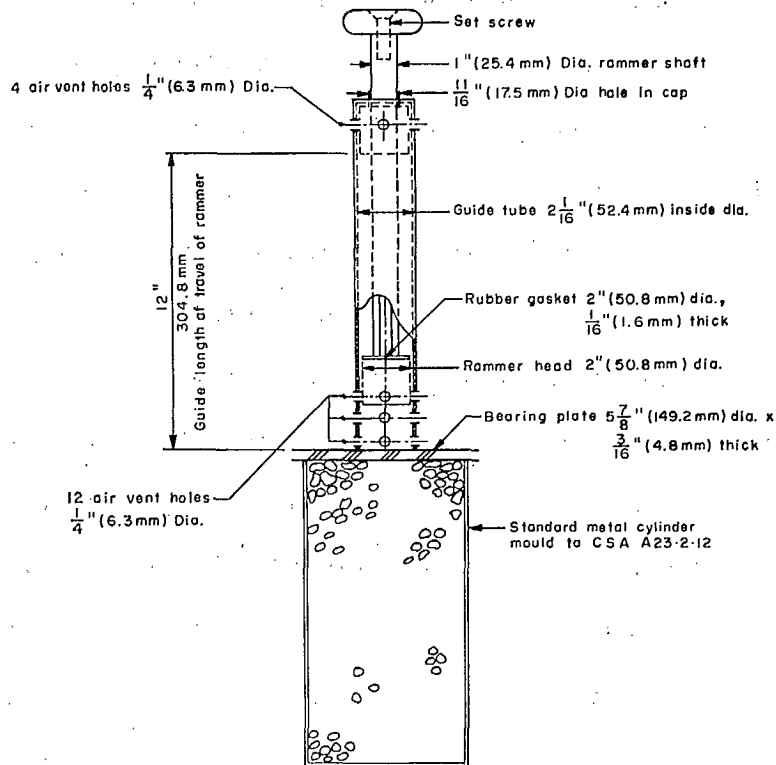
Fig. 7. Rammer and a cylinder mould for no-fines concrete.

From Reference (10).

Fig. 8. Casting of 6 x 12-in. (152 x 305-mm) cylinders of no-fines
concrete.

Top: Concrete being hand rodded in cylinder moulds;
Bottom: Steel trowel being used to level top of concrete in a
steel cylinder.
From Reference (12).
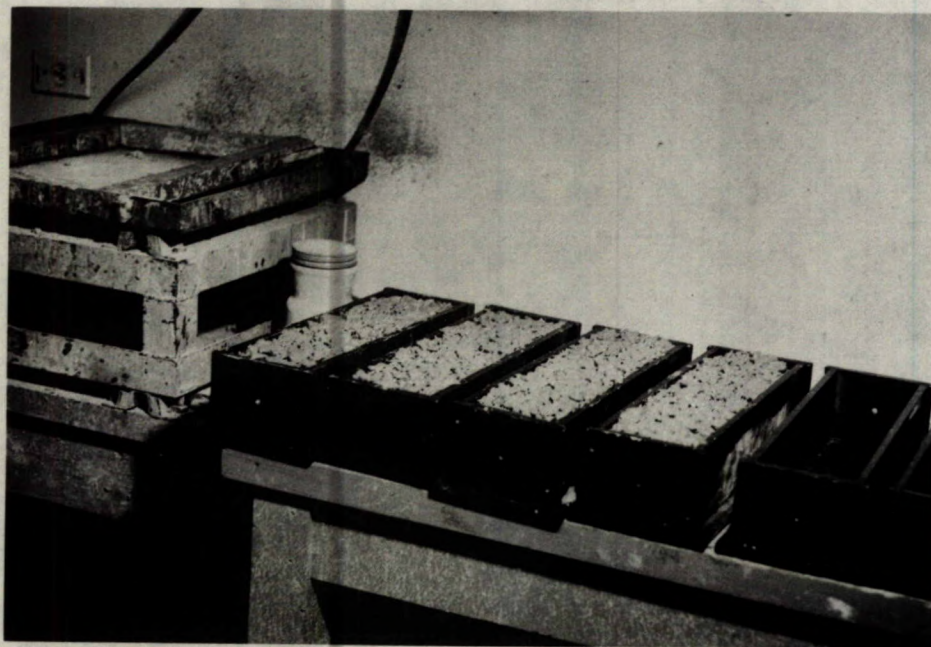
Fig. 9. Test prisms, 3 1/2 x 4 x 16 in. (89 x 102 x 406 mm), immediately
after casting.
From Reference (12).

CURING

Conventional Curing

As with conventional concrete, adequate moist-curing of no-fines concrete is essential. It should be kept moist for a period of from 3 to 7 days after placing, particularly in dry, windy climates because dry, hot winds can go through this type of concrete.

Rapid drying is more serious for no-fines concrete than for conventional concrete because dry paste fails to hold the aggregate particles together. It has been shown that no-fines concrete made with dense, non absorptive aggregates without damp-curing reached only 43 per cent of the compressive strength of similar concrete moist-cured for 7 days (14).

The following moist-cured periods have been suggested for no-fines concrete made with different types of portland cements (11), placed and cured at about $60^{\circ}F$ ($15.5^{\circ}C$).

With normal portland cement............................. 7 days

With rapid-hardening portland cement..................... 4 days

With portland blast furnace cement...................... 10 days

At lower temperatures longer curing periods will be mandatory.

Electrical Curing

In the U.S.S.R., no-fines concrete has been used in very cold climates where the construction season is restricted to a few months in a year and electric curing has been employed successfully to achieve rapid gain in strength (13). In one instance, it was placed during the winter

months when the average temperature was 9°F (-12.8°C) and the lowest recorded

temperature minus 44°F (-42°C) with wind velocities of up to 27 mph (43.2 kph)

Experience in electrical curing in the U.S.S.R. has indicated:

(a) that curing temperature should not exceed 95°F (35°C) to avoid excessive drying which occurs at a temperature of 104 to 108°F (40 to 42°C). When excessive drying is suspected, the electric curing should be turned off, and the concrete should be cooled down to about 68 to 79°F (20 to 26°C) before recommencing the electrical curing,

(b) that consumption of electricity is about 25 to 30 per cent less than for dense concrete,

(c) that a curing cycle of about 24 hours is required to obtain 60 per cent of the 28-day strength,

(d) that the electrodes should consist of steel rods. These should be spaced uniformly and in a vertical position.

TIMES FOR REMOVAL OF FORMWORK

Under normal conditions, forms can be removed after 24 hours.

However, it is stressed that as no-fines concrete has virtually no cohesion,

forms must remain in place until the cement paste has hardened and developed

sufficient strength to hold together the aggregate particles. Table 2 gives

the times for removal of formwork for vertically faced construction (11).

Horizontal formwork supporting no-fines concrete, as in lintels,

should not be removed for at least 3 days and the concrete should not be

loaded during this period.

TABLE 2

Times for Removal of Formwork from Walls of No-Fines Concrete*

Air temperature during curing of concrete	Minimum time for form removal	Minimum time before applying load
Not lower than 70°F (21.1°C)	24 hours	3 days
Between 50 and 70°F (10.0 to 21.1°C)	2 days	5 days
Between 40 and 50°F (4.4 to 10.0°C)	3 days	10 days
Below 40°F (4.4°C)	Same precautions must be taken as for conventional concrete.	

*From Reference (11).

This Table is applicable to walls of single storey height.

STRENGTH AND ELASTIC PROPERTIES

Compressive Strength

The compressive strength is considerably lower than that of conventional portland cement concrete and generally varies between 200 psi (1.4 MN/m^2) and 2000 psi (13.7 MN/m^2). Tables 3 to 5 give compressive strengths for varying water-cement and aggregate-cement ratios (2, 11, 14). A view of test cylinders using different coarse aggregate gradings is shown in Fig. 10. The results of long-term tests on the compressive strength of no-fines concrete as reported by Sidwell(15) are shown in Fig. 11.

TABLE 3

Compressive Strength of No-Fines Concrete for various Water-Cement
and Aggregate-Cement Ratios*

Aggregate-Cement Ratio by Volume	Water-Cement Ratio by Weight	Age of Test, days	Density		Cement Content		Compressive Strength	
			lb/cu ft	kg/cu m	lb/cu yd	kg/cu m	psi	MN/m^2
6:1	0.38	3	125.8	2015	436	259	1295	8.9
	0.38	7	125.4	2009	436	259	1660	11.4
	0.38	28	124.8	1999	436	259	2080	14.3
8:1	0.41	3	120.0	1922	326	193	850	5.8
	0.41	7	119.5	1914	326	193	1055	7.2
	0.41	28	119.4	1913	326	193	1365	9.4
10.1	0.45	3	116.7	1869	261	155	625	4.3
	0.45	7	116.4	1865	261	155	780	5.4
	0.45	28	116.2	1862	261	155	1015	7.0

*From Reference (2).

All strengths determined on 6-in. (152-mm) cubes.

Aggregate used was 0.75 in. (19-mm) gravel.

TABLE 4

Average Compressive Strength of No-Fines Concrete Using Different Aggregates*

Type of Aggregate	Dry Density		Compressive Strength at 28 days	
	lb/cu ft	kg/cu m	psi	MN/m^2
Rounded Quartzite gravel	115	1842	1,250	8.6
Irregular Flint gravel	99	1586	700	4.8
Crushed Limestone	114	1826	1,000	6.9
Crushed Granite	106	1698	1,100	7.5

*From Reference (15).
Water-cement ratio (by weight) used = 0.40
Aggregate-cement ratio (by weight) used = 1.80

TABLE 5

Compressive Strength of No-Fines Concrete Made with Different Gradings of Crushed Limestone*

Water-Cement Ratio by Weight	Aggregate Grading**	Aggregate-Cement Ratio by Weight	Cement Content		Unit Weight of Fresh Concrete		Compressive Strength on 6 x 12-in (152 x 305-mm) Cylinders			
							7 days		28 days	
			lb/cu yd	kg/cu m	lb/cu ft	kg/cu m	psi	MN/m^2	psi	MN/m^2
0.36	A	8:1	605	359	119.2	1910	1030	7.1	1230	8.4
			614	364	116.8	1871	700	4.8	975	6.7
			622	369	116.0	1858	795	5.5	1090	7.5
			620	368	113.2	1813	880	6.0	815	5.6
0.36	B	9:1	618	368	117.6	1884	680	4.7	1040	7.1
			606	360	113.6	1820	590	4.0	825	5.7
			613	364	112.4	1801	635	4.4	745	5.1
0.36	C	7:1	608	361	117.2	1877	1075	7.4	1280	8.8
			616	365	115.6	1851	790	5.4	1030	7.1
			607	360	114.0	1826	815	5.6	1000	6.9
			621	368	114.0	1826	945	6.5	950	6.5

*From Reference (12).
**Grading A = minus 3/4 in. plus 3/8 in. (minus 19 mm plus 9.5 mm)
  Grading B = minus 3/4 in. plus 1/2 in. (minus 19 mm plus 12.7 mm)
  Grading C = minus 1/2 in. plus 3/8 in. (minus 12.7 mm plus 9.5 mm)
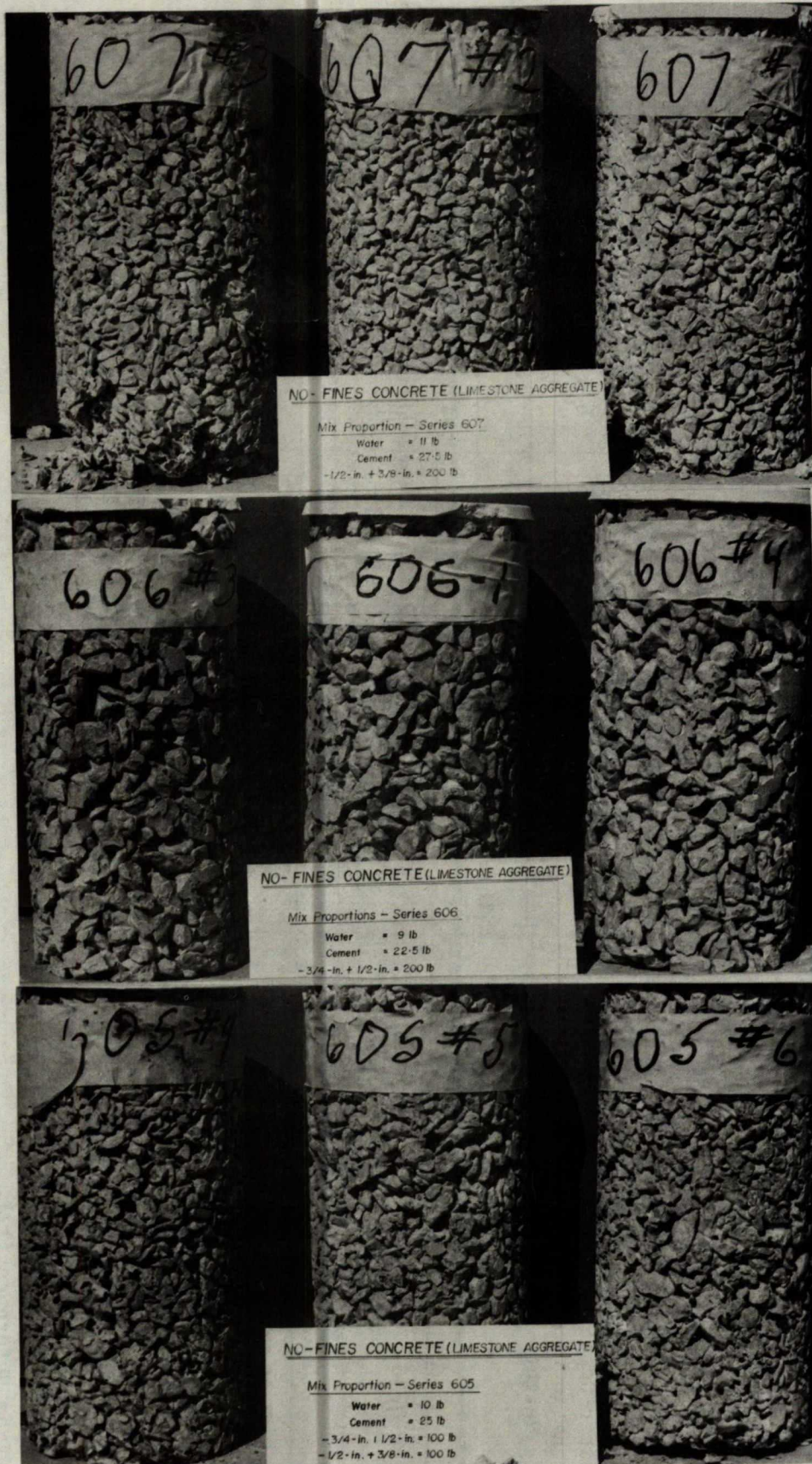
Fig 10. Test cylinders, 6 x 12 in. (152 x 305 mm) of no-fines concrete made with different coarse aggregate gradings.

From Reference (12).

Modulus of Rupture

As with compressive strength, modulus of rupture of no-fines concrete is considerably lower than that of conventional concrete. The same is true for its shear strength. Table 6 gives some values for modulus of rupture as reported by various investigators (7, 12, 16). It will be seen that values are generally less than 385 psi (2.6 MN/m^2).

The results of long-term tests on flexural strength as reported by Sidwell (15) are reported in Fig. 12.

The ratio of modulus of rupture to compressive strength expressed as a percentage varies between 10.8 and 31.0 per cent. The comparable value of this ratio for conventional concrete is 19 per cent (17). Because of its low flexural and shear strength, the use of no-fines concrete is limited to those applications only where low bending and low shear loadings are to be encountered.

Bond Strength

No-fines concrete is not usually used in reinforced concrete because the strength of bond between this type of concrete and steel reinforcement is low. In those cases where reinforcement has to be used it is usually coated with a thin layer of about 0.125 in. (3.2 mm) of cement paste by means of "Gunite-ing" to improve the bond strength and to provide protection against corrosion. For design purposes, the bond strength between grout-covered reinforcement and no-fines concrete may be taken as 40 psi (0.27 MN/m^2).

According to Short and Kinniburgh (4), window and door openings are a source of weakness, not only because of the stress concentration at the corners in this type of construction, but also because of the difficulty in ensuring that the concrete placed at window sills is strong enough. Reinforcing steel is therefore frequently placed at wall openings, particularly in external walls; at window sills reinforced concrete made with graded normal weight aggregate is placed. (Fig. 13).

TABLE 6

Modulus of Rupture of No-Fines Concrete

Reference No.	Mix Proportions			Prism Size	Type of Loading	Modulus of Rupture								Ratio, Modulus of Rupture to Compressive Strength of Cylinders* at 28 days
	Aggregate Size and Type	Water-Cement Ratio (by weight)	Aggregate-Cement Ratio			Age at Test, Days								
						7		14		28		91		
						psi	MN/m²	psi	MN/m²	psi	MN/m²	psi	MN/m²	
7 (Peterson 1943)	0.75-in. (19-mm) gravel	0.44	9.8:1 (by weight)	30x30x6 in. (760x760x152mm)	Centre point with 24-in. (608-mm) span	–	–	–	–	101	0.7	–	–	0.11
16 (Boyd 1946)	0.75-in. (19-mm) Basalt	0.42	8.0:1 (by volume)	4x4x6 in. (102x102x152mm)	Centre point	179	1.2	–	–	215	1.5	225	1.5	0.27
12 (Malhotra 1973)	0.75-in. (19-mm) Crushed Limestone	0.36	8.05:1 (by weight)	3.5x4x16 in. (89x102z408mm)	Middle third	–	–	–	–	385**	2.6	–	–	0.31
(Malhotra 1973)	0.75-in. (19-mm) Crushed Limestone	0.41 0.46 0.45 0.46	8.0:1 10.1:1 10.1:1 10.1:1 (by weight)	3.5x4x16 in. (89x102x408mm)	Middle third	–	–	355 330 315 225	2.4 2.3 2.2 1.5	–	–	–	–	0.36 0.41 0.31 0.20

*Cylinder size = 6 x 12 in. (152 x 305 mm)
**Tested at 36 days, whereas cylinders were tested at 28 days.
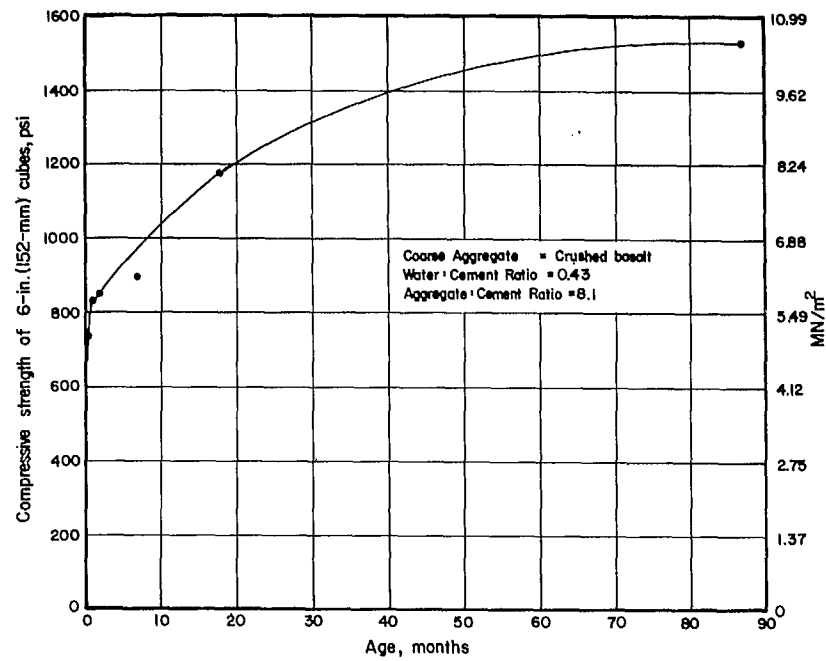
Fig. 11. Relationship between age and compressive strength of no-fines concrete.
From Reference (15).
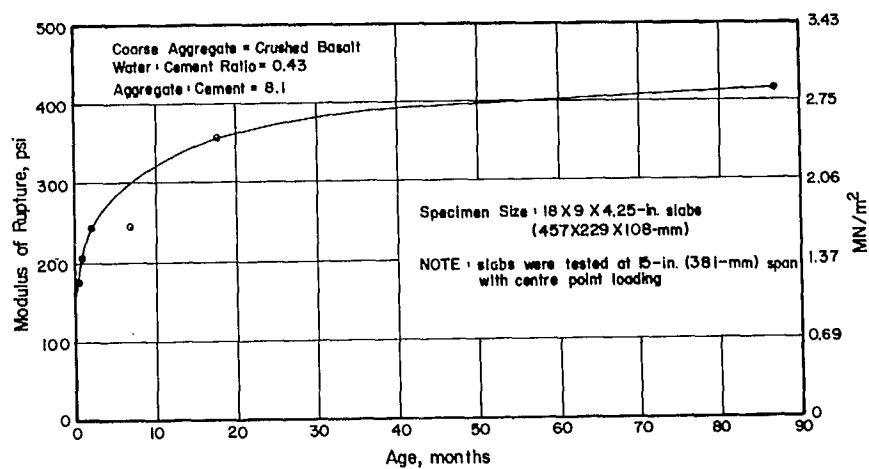
Fig. 12. Relationship between age and modulus of rupture of no-fines concrete.
From Reference (15).

TABLE 7

Bond Strength of No-Fines Concrete as Determined by Pull-Out Tests*

Type of Concrete	Mix Proportions	Compressive Strength of 6 x 12-in. (152 x 305-mm) cylinders		Bond Stress** using 0.75-in.(19-mm) round deformed bar			
				At slip of 0.0001 in.(0.0025 mm)		At max load	
		psi	MN/m^2	psi	MN/m^2	psi	MN/m^2
No-Fines	Aggregate-Cement Ratio 11.5 : 1 (by weight) Water-Cement Ratio 0.5 (by weight)	560	4	181	1.2	330	2.3
Conventional	1 : 2.8 : 3.2 (by volume)	2620	18	930	6.4	2620	18.0

* From Reference (7)
** Each value is the average of three test results.
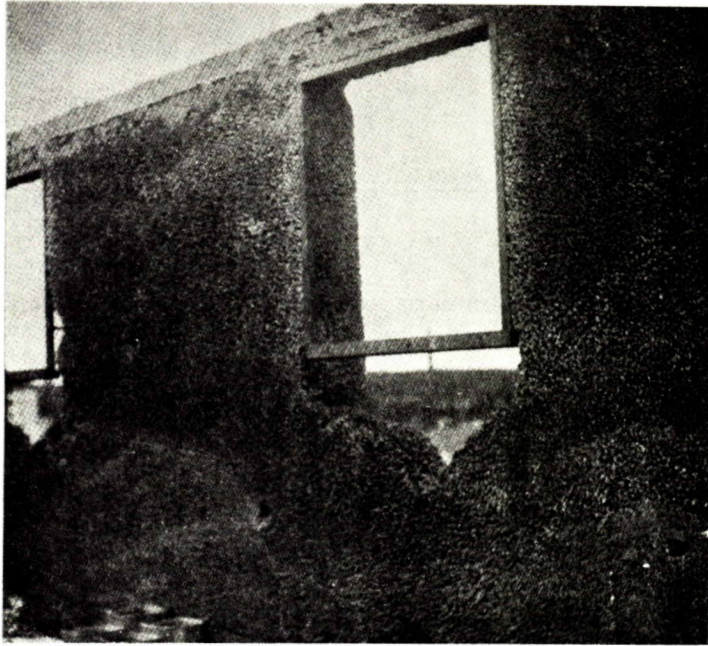
Fig. 13. Window sill where space has been left for reinforced
concrete made with graded normal-weight aggregates.

From Reference (4).

The bond strength of no-fines concrete as determined by pull-out tests is given in Table 7.

Modulus of Elasticity

The typical modulus of elasticity values for no-fines concrete are given in Table 8 (18). It has been reported that the modulus tends to diminish with age (4).

Resistance to Failure by Diagonal Tension

Limited data are available on resistance to failure by diagonal tension. In one investigation (7) beams 58 in. long, 6 in. wide and 13.5 in. deep (1473 x 152 x 343 mm) were tested. Two 0.375-in. (9.5-mm) round deformed bars, hooked at each end were used as reinforcement. The steel bars in three of the beams were given a coating of cement grout immediately before placing; uncoated bars were used in the other three beams.

The computed shear stress in the beams at failure was about 80 psi (0.5 MN/m^2). This is about half of that expected for a regular concrete with a compressive strength of 2500 psi (17.2 MN/^{2}m). The resistance to failure by diagonal tension did not change appreciably when the reinforcing bars were coated with a cement-water grout immediately before placing (Table 9).

Relation Between Compressive Strengths of Cylinders and Cubes

Most of the investigations of no-fines concrete have been performed in the United Kingdon and Western Europe where the standard test specimen for determining the compressive strength of concrete is a 6-in. (152-mm) cube. To convert cube compressive strengths to correspond to strengths of 6 x 12-in. (152 x 305-mm) cylinders for use in North America a reduction factor of about 30 per cent is recommended (19). This factor for no-fines concrete is somewhat higher than that for conventional concrete due to the relatively low shear strength of the former.

TABLE 8

Modulus of Elasticity of No-Fines Concrete*

Compressive Strength of 6-in. (152-mm) cubes		Young's Modulus of Elasticity,	
psi	MN/m^2	psi	MN/m^2
700	4.8	1.5×10^6	1.0×10^4
500	3.4	1.3×10^6	0.9×10^4
350	2.4	1.0×10^6	0.7×10^4

*From Reference (18).

TABLE 9

Resistance to Failure by Diagonal Tension*

Size of Beams	Computed Shearing Stress				Compressive Strength of Cylinders	
	First Crack		Max Load			
	psi	MN/m^2	psi	MN/m^2	psi	MN/m^2
58 in. x 6 in. x 13.5 in. deep (1473 x 152 x 343-mm)						
(a) Bars coated with grout	38	0.3	80	0.5	785	5.4
(b) Uncoated bars	31	0.2	77	0.5	650	4.5

*From Reference (7).
Notes: 1. Each result is the average of tests on three beams.
2. A 48 in.(1219-mm) span was used with beams being tested at mid-span.
3. Mix proportions: Water-cement ratio by weight   = 0.50
Aggregate-cement ratio by weight = 11.5
Cement content = 235 lb/cu yd (139 kg/cu m)
Aggregate type = pea gravel.

Relation of Strength of Cubes to that of Walls

The Building Research Station, England, performed studies to
determine relationships between the compressive strength of cubes and the
strength of wall units made of no-fines concrete (2). In one investigation
three wall panels were cast, each 9 ft high, 4.5 ft wide and 10 in. thick
(27.4 x 13.72 x 0.254 m), made of concrete having aggregate-cement ratio of
8:1 and using plus 0.75 in., minus 0.375 in. (plus 19-mm minus 9.5 mm)
crushed river gravel as aggregate. A large number of control cubes were
cast at the same time and both walls and cubes were tested at about 33 days.
The walls and cubes gave very consistent results and the crushing strength
of walls ranged from 0.50 to 0.54 of the mean strengths of the cubes which
was 1280 psi (8.8 MN/m^2). The lower strength of the walls was attributed
to the slenderness ratio effect and to the lower unit weight of the walls
compared with those of the cubes.

FREEZE-THAW RESISTANCE

Determination of the freeze-thaw resistance have been reported. In
one investigation (12), prisms 3½ x 4 x 16-in. (89 x 102 x 406-mm) in size,
were subjected to repeated cycles of freezing in air and thawing in water
according to an ASTM test method*. The automatic freeze-thaw unit used
performed 8 cycles per day. One complete cycle from 40 ± 3°F (4.4 ± 1.6C)
to 0 ± 3°F (-17.8 ± 1.6C) and back to 40 ± 3°F (4.4 ± 1.6C) required 2 hours
and fifty-one minutes. A summary of the test results is shown in Table 10.

---

*ASTM Designation C666-73: Standard Method of Test for Resistance of Concrete
to Rapid Freezing and Thawing, 1973.

The tests indicated that no-fines concrete prisms without air-entraining agent had poor resistance to freezing and thawing and broke into two halves after less than 73 cycles; the corresponding prisms incorporating an air-entraining agent were able to withstand up to 274 freeze-thaw cycles (Fig. 14).

It is believed that, in situations where no-fines concretes may have to be exposed to conditions of freeze-thaw, consideration should be given to the incorporation of air-entraining agents in the mix.

DRYING SHRINKAGE

The total drying shrinkage of no-fines concrete is considerably lower than that of conventional concrete in which coarse aggregate of the same type is used (Table 11). When made with crushed limestone or river gravel, the shrinkage is of the order of 200×10^{-6}, about half that of conventional concrete. This is explained by the fact that cement paste is present as a thin coating only and shrinkage on drying is restrained by the aggregate particles. However, the rate of drying shrinkage is generally much more rapid than that of conventional concrete because the paste has a large surface area exposed to air. In no-fines concrete, 50 to 80 per cent of the total shrinkage takes place within 10 days; the corresponding value for conventional concrete is 20 to 30 per cent. It has also been shown that total shrinkage movement may be completed in little over a month.

TABLE 10

Freeze-Thaw Resistance of No-Fines Concrete*

Mix No.	Water/Cement Ratio* (by weight)	Type of Admixtures Used	Average** Number of cycles after which the prisms were removed from the freeze-thaw machine	Condition of prisms on removal from the freeze-thaw machine
1	0.41	No admixtures used	73	Prisms were badly damaged and disintegrated on handling
2	0.41	No admixtures used	73	Prisms were badly damaged and disintegrated on handling
3	0.41	An air-entraining agent used	266	Prisms were damaged to some degree
4	0.46	No admixtures used	56	Prisms completely disintegrated
5	0.46	No admixtures used	56	Prisms completely disintegrated
6	0.46	An air-entraining agent used	249	Prisms damaged to some degree

*From Reference (12).

**In each test, two $3\frac{1}{2}$ x 4 x 16-in. (89 x 102 x 406-mm) prisms were subjected to freeze-thaw cycling

Note: When an air-entraining agent was used, the entrained air content was estimated from the cement paste fraction using a method somewhat identical to ASTM Standard C185-71. The estimated value of the entrained air was approximately 3 per cent compared to 2 per cent for non air-entrained cement paste.

PRISMS BEFORE FREEZE - THAW CYCLING
(Mix Series 605)

"NON AIR - ENTRAINED" NO-FINES CONCRETE

NO. OF FREEZE - THAW CYCLE = 56
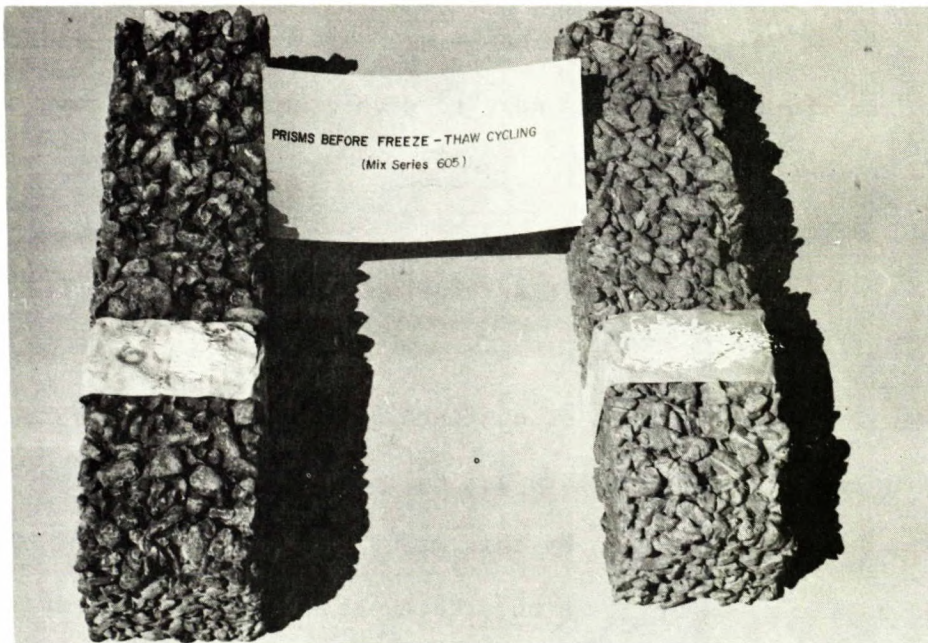
Fig. 14. Test prisms before and after freeze-thaw cycling.

From Reference (12).

As the two types of concrete have different rates and coefficients of shrinkage, it is advisable they not be used in conjunction. Where necessary to use the two materials next to each other, extreme care should be exercised.

CAPILLARY ACTION

Due to the very nature of no-fines concrete, water does not penetrate this material by capillary action. It is generally agreed that approximate depth of penetration by this means under conditions of high humidity and no air movement(7) is no greater than two to three times the diameter of the largest aggregate for 3/4-in. (19-mm) aggregates, i.e., 1.5-in. (37.5-mm). For aggregate sizes of 0.5 in. (12.7 mm) and 3/8 in. (73.5 mm), penetration of up to 2.5 in. (73.5 mm) has been reported (14). The penetration is higher for no-fines concrete made with conventional aggregates than that made with clinker aggregates.

PERMEABILITY

The permeability of no-fines concrete is very high. Water and air can pass freely through its large open voids. No quantitative data are available on this physical property.

TABLE 11

Drying Shrinkage of No-Fines Concrete*

Aggregate	Ratio of Cement: aggregate, by volume	Water/cement ratio, by weight	Drying shrinkage, (at 50°C and 17% relative humidity) %
Natural river gravel	1 : 8 1 : 10 1 : 12 1 : 2 : 4 dense concrete	0.40 0.45 0.50	0.018 0.018 0.018 0.035
Whinstone	1 : 8 1 : 10 1 : 12 1 : 2 : 4 dense concrete	0.35 0.40 0.45	0.022 0.023 0.028 0.049
Air-cooled slag	1 : 8 1 : 10 1 : 12 1 : 2 : 4 dense concrete	0.40 0.45 0.50	0.025 0.020 0.022 0.038
Crushed limestone	1 : 8 1 : 10 1 : 12 1 : 2 : 4 dense concrete	0.40 0.45 0.50	0.016 0.019 0.022 0.033
Clinker	1 : 6 1 : 8 1 : 10 1 : 2 : 4 dense concrete	0.375 0.425 0.475	0.033 0.025 0.040 0.038

*From Reference (4).

ABSORPTION OF WATER

The absorption of water is considerably lower than for conventional concretes. In one investigation (7), specimens were immersed in water for 24 hours. The increase in weight expressed as a percentage of oven-dry weight was 2.6 per cent. The corresponding values for good conventional concrete, as reported elsewhere (18), range between 7.4 and 12.9 per cent.

NO-FINES CONCRETE IN RELATION TO OTHER LIGHTWEIGHT CONCRETES

According to the American Concrete Institute (20), structural concrete having a unit weight in the range 90 to 115 lb/cu ft (1440-1850 kg/cu m) is classified as structural lightweight concrete. Under this broad definition, no-fines concrete can be considered as a lightweight material. The other two major types of lightweight concretes are those made with lightweight aggregates, and aerated concrete; the latter type is made by creating gas bubbles in a cement slurry, which, when it sets, leaves a sponge-like cellular structure.

No-fines concrete in relation to the other types is depicted in Fig. 15, and some of the basic properties of no-fines concrete in comparison with other lightweight concrete are given in Table 12.
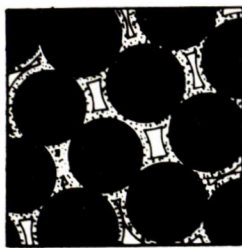
1. No-Fines.   2. Lightweight Aggregate.   3. Aerated.
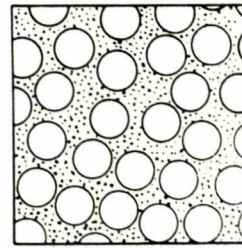
Fig. 15. No-fines concrete in relation to other types. From Reference (4).

TABLE 12

Comparison of Properties of No-Fines Concrete with those of other Lightweight Concretes

Type of concrete	Aggregate	Unit weight of aggregate		Unit weight of fresh concrete		Compressive strength of 6x12-in. (152x305-mm) cylinders	
		lb/cu ft	kg/cu m	lb/cu ft	kg/cu m	psi	MN/m^2
No-fines concrete	Natural aggregate	85-100	1362-1602	100-120	1602-1922	450-1500	3.1—10.3
	Lightweight aggregate	30-65	481-1041	55-75	881-1201	300-700	2.1— 4.8
Aerated concrete	–	–	–	–	–	150-500	1.0 — 3.4
Structural semi-lightweight concrete**	Blast furnace slag, expanded clay or shale	35-115	561-1842	85-115	1362-1842	1500-4500	10.3—30.9

*From Reference (4).
**Lightweight coarse aggregate and natural sand.

THERMAL PROPERTIES OF NO-FINES CONCRETE

Thermal Conductivity

The coefficients of thermal conductivity are given in Table 13, together with the values for conventional concrete.

A wall of no-fines concrete made with conventional aggregates has a thermal conductivity comparable with a wall of solid brickwork of the same thickness. Thus, to achieve the same degree of insulation as for an 11-in. (279-mm) cavity wall, an 8-in. (203-mm) thick no-fines concrete wall will need added insulation. However, if made with lightweight aggregates such as clinker with a higher insulation value than conventional aggregate, a wall of no-fines concrete 8 inches (203 mm) thick would be comparable to a brick cavity wall of 11 inches (274 mm) thickness.

In-situ measurements of the thermal conductivity of 12 x 12 x 1-in. (0.305 x 0.305 x 0.0254 m) slabs of conventional and no-fines concrete have been made during the first seven days after casting (22). The thermal conductivity decreases by 30 per cent from its initial value during this period and subsequently remains constant at a value of 1.6 W.m/m^2 $^\circ$C*. The results obtained have been used, together with data on the heat of hydration of the cement and environmental conditions to predict temperature distributions in fresh slabs of conventional and no-fines concrete (22). The predicted temperatures lay within 1°C (1.8°F) of the measured temperature for 86 per cent of the time of prediction and within 0.5°C (0.9°F) for 62 per cent of the time.

$$*\frac{1.0 \text{ W.m}}{\text{m}^2 \, ^\circ\text{C}} = 0.578 \frac{\text{Btu x ft}}{\text{ft}^2 \text{ x hr x } ^\circ\text{F}} = 0.857 \frac{\text{kg-cal x m}}{\text{m}^2 \text{ x hr x } ^\circ\text{C}}$$

TABLE 13

Typical Values of Thermal Conductivity of
No-Fines and Conventional Concrete*

Type of concrete	Type of aggregate	Thermal conductivity**		Density of Concrete	
		$\dfrac{Btu \times ft}{ft^2 \times hr \times {}^{\circ}F}$	$\dfrac{Kg\text{-}cal \times m}{m^2 \times hr \times {}^{\circ}C}$	lb/ft^3	kg/m^3
No-fines	Conventional	0.48	0.74	110	1760
	Lightweight	0.27	0.42	80	1280
Conventional	Igneous	0.83	1.28	159	2540
	Dolomite	2.13	3.28	160	2560
	Lightweight (oven dried)	0.08 - 0.35	0.12 - 0.52	30 - 110	480-1760

*From References (4, 18).
**Thermal conductivity. This is the quantity of heat which will flow through a unit area in a unit time when a unit difference of temperature exists between the faces of unit thickness of material.

Thermal Transmittance

Thermal transmittances or "U" values* of various wall thicknesses are given in Table 14.

Thermal Expansion

The linear coefficient of thermal expansion of no-fines concrete made with 0.75-in. (19-mm) gravel concrete is of the order of 6.0×10^{-6} per $^\circ$F (7) and is in the same range as that for conventional concrete.

Thermal Performance in Floors

Experimental studies have been performed by the Cement and Concrete Association, England, to determine the heat drop in a warm body when in contact with floors made of different composite materials. The loss of heat from the body results in a sensation of "coldness" and Table 15 summarizes the relative coldness of floors of different materials.

---

*Thermal Transmittance (U). The 'U' value of a wall or roof (which may or may not be homogeneous) is the quantity of heat, transmitted in a unit time through a unit area of wall or roof when the temperature of the air on the two sides differs by one degree.

Whilst the k-value applies to a single definable material and thus has general application and significance, the U-value refers to the heat transfer through some specific wall system, usually a composite system, such as brickwork rendered and plastered, or brickwork plastered only. Basically, however, the "U"-value is made up of the k-values of the individual materials making up the thickness of the wall and so in the line of resistance to heat flow.

TABLE 14

Calculated U-Values for Different Thicknesses of No-Fines Wall Construction*

Wall construction	Mix proportions of aggregate to cement (by volume)	"U" Values** of no-fines concrete walls with different aggregates and varying mix proportions and wall thicknesses				
		Gravel	Whinstone	Blast furnace slag	Limestone	Clinker
8 inches (203mm) of concrete and one inch (25mm) of rendering and plastering	6:1 8:1	– 0.39 (0.60)	– 0.37 (0.57)	– 0.31 (0.48)	– 0.39 (0.60)	0.30 (0.46) –
10 inches (254mm) of concrete and one inch (25mm) of rendering and plastering	6:1 8:1	– 0.34 (0.52)	– 0.33 (0.51)	– 0.27 (0.41)	– 0.35 (0.54)	0.26 (0.40) –
12 inches (302mm) of concrete and one inch (25mm) of rendering and plastering	6:1 8:1	– 0.31 (0.48)	– 0.29 (0.45)	– 0.24 (0.37)	– 0.31 (0.48)	0.23 (0.35) –
11 inches (279mm) of brick cavity wall and one inch of rendering and plastering	–	0.29 (0.45)	–	–	–	–
11 inches (279mm) of brick cavity wall, unrendered	–	0.30 (0.46)	–	–	–	–

*From Reference (4).
**Units for "U" values are: $\dfrac{Btu}{ft^2 \text{ x hr x } {}^\circ F} \left(\dfrac{kg\text{-}cal}{m^2 \text{ x hr x } {}^\circ C} \right)$

Note: A 12-in. (302-mm) thick wall of no-fines concrete using gravel or crushed rock aggregate has a "U" value not substantially different from an 11-in. (279-mm) brick wall.

TABLE 15

Relative Coldness of Floors of Various Construction*

Floor construction	Relative coldness[+]
1. Reference floor: compressed cork 4-in. (102-mm) thick	1.0
2. No-fines concrete floor with 1½-in. (37.5-mm) grano topping	2.8
3. Conventional concrete floor with 1½-in. (37.5-mm) grano topping	4.2

*From Reference (11).

[+]Relative coldness = $\dfrac{\text{Loss of heat from a body in contact with a floor under investigation}}{\text{Loss of heat from a body in contact with a reference floor}}$

Fire Resistance

Investigations have been performed in the United Kingdom to measure the fire resistance of non load-bearing walls of no-fines concrete. The tests were done according to British Standard 476:1932 on both monolithic and block walls each made from two different aggregates, representative of high and low silica content aggregates. All the walls were 10 ft x 10 ft x 6 in. (2.54 m x 2.54 m x 152 mm) and were rendered on both faces. A summary of the test results is given in Table 16. The following conclusions were drawn from the above investigation (21).

> "Restrained walls 6 in. (152 mm) thick, of no-fines concrete made from natural aggregates representative of the high and low silica content rocks and rendered on both faces, have been shown to possess a fire resistance which is sufficient for most classes of buildings, and compares favourably with the ratings obtained by other types of construction. For example, clay brick walls 4.25-in. (107.9-mm) thick, plastered 0.5 in. (12.7 mm) on each face are rated as constructions of 2-hr fire resistance.
>
> The walls of low silica aggregate were superior to the corresponding construction of high silica aggregate. A lower fire resistance was obtained for the block wall of either aggregate than for the corresponding monolithic wall.
>
> It is reasonable to assume that the fire resistance of no-fines concrete walls of similar construction to those tested, but using different aggregates, would not be less than that of the quartzite specimens".

TABLE 16

Summary of Results of Fire-Resistance Tests of No-Fines Concrete Walls*

Specimen	Aggregate	Type of construction	Average temperature of unexposed face – $^{\circ}C(^{\circ}F)$						Fire-resistance		Mode of failure
			1-hr	2-hr	3-hr	4-hr	5-hr	6-hr	hr	min	
1	Crushed quartzite	Monolithic	25.6 (78)	26.7 (80)	28.3 (83)	39.4 (103)	–	–	4	14	Rendering fallen from both faces of wall revealing horizontal fissure through which furnace was visible from unexposed side
2	Crushed quartz	Block	21.1 (70)	22.8 (73)	25.0 (77)	–	–	–	3	15	Rendering fallen from both faces of wall so that furnace was visible from unexposed side through unmortared vertical construction joint
3	Crushed basalt	Monolithic	-5.0 (23)	22.8 (73)	29.4 (85)	30.6 (87)	35.0 (95)	39.4 (103)	No failure after 6 00		–
4	Crushed basalt	Block	10.0 (50)	22.8 (73)	26.7 (80)	32.8 (91)	56.1 (133)	–	5	02	Permitted rise of maximum temperature of unexposed face exceeded

* From Reference (21).

SOUND INSULATION AND SOUND ABSORPTION COEFFICIENTS OF NO-FINES CONCRETE

The effectiveness of solid walls in reducing transmitted sound is proportional to the weight of the wall. Because of this, the sound insulation* of no-fines concrete walls is not better than solid brick walls of comparable thickness and may, in fact, be somewhat inferior. However, a high sound absorption** has been claimed. Table 17 gives values of sound absorption coefficients for both types of concrete.

APPLICATIONS

No-fines concrete has been used in a variety of ways in the construction industry. To date, its large scale application has been for load-bearing, cast-in-place external walls of single and multi-storey housing and, in recent years, in tall structures. It is more economical when construction projects are relatively large because of high initial cost of formwork for cast-in-place construction.

It has also found considerable use as a damp-proofing sub-base material for concrete floors cast on grade. Some other possible applications are for small retaining walls, and for soil and ground drainage. It should also find use in temporary structures because of low initial cost and the ease with which it can be broken and recycled.

No-fines concrete is attractive as a construction material in northern Canada because of its higher thermal insulating property and low cement content per cu yd compared with conventional concrete. It should be emphasized that for construction in northern Canada, cement has to be

---

*Sound insulating materials are those which reduce the transmission of sound through them.
**Sound absorbing materials are those which reduce the sound reflected from a surface.

TABLE 17

Sound Absorption Coefficients of No-Fines Concrete*

Materials	Absorption coefficients		
	Low frequency 125 c/s	Medium frequency 500 c/s	High frequency 2000 c/s
Acoustic no-fines concrete 6 in.(152 mm) thick,made with 3/8- to 3/16-in. (9.5-mm to 4.7-mm) aggregate.	0.25	0.55	0.70
Acoustic no-fines concrete 6 in.(152 mm) thick,made with 3/4-to 3/8-in.(19-mm to 9.5-mm) aggregate.	0.05	0.70	0.75
Conventional concrete	0.01	0.02	0.02

*From Reference (4).

transported over long distances, skilled manpower is in short supply and buildings are usually only a few storeys high. The U.S.S.R. has been successfully using no-fines concrete in its northern regions for a considerable period of time. The wall units can be cast in-situ or prefabricated on site. The latter method appears to be more suitable because of the lack of skilled manpower in the region and the short construction season of only two to four months. In Australia, blocks of no-fines concrete have been used for wall construction (Fig. 16).

No-fines concrete appears eminently suitable for use as a back-fill material in some mines. The only prerequisite is the coarse aggregate fraction, which can easily be obtained by screening the waste rock materials. For such backfill materials compressive strength requirements are rather low. The only requirement appears to be that the hardened material should have compressive strengths of the order of 70 psi (0.50 MN/m^2) and should be capable of being placed without external compaction. No-fines concrete meets both of these requirements.

SUMMARY OF ADVANTAGES AND LIMITATIONS

The main advantages and limitations of no-fines concrete in comparison with conventional concrete are as follows:

Advantages

Saving in Materials - As no-fines concrete contains no sand and consequently requires considerably less cement per cu yd of concrete, there is a direct saving in materials. This aspect becomes particularly important when cement has to be transported over long distances, such as in northern Canada.

Fig. 16. Walls of blocks of no-fines concrete under construction in
Australia.

From Reference (14).

High Thermal Insulation Value - Because of its very nature which allows the formation of large voids, it has better insulating characteristics than conventional concrete.

Low Unit Weight - It is a type of lightweight concrete and thus possesses some of the advantages associated with lightweight concrete construction.

Low Drying Shrinkage - Drying shrinkage is relatively low compared with conventional concrete.

Elimination of Capillary Action - There is no transmission of water by capillary action because of the absence of capillary passages.

Low Pressures on Formwork During Construction - Unit weight is about two-thirds that of conventional concrete from the same aggregate. The pressure on formwork is therefore much less than that of conventional concrete and the formwork need not be water tight. Consequently, cheaper formwork may be used.

Limitations

Low Strength - The compressive, flexural and bond strengths of no-fines concrete are considerably lower than those of conventional concrete made with similar aggregates. This is one of the major drawbacks of this type of concrete. The use of reinforcement is generally not recommended.

High Permeability - It has very high permeability compared with conventional concrete. This is a decided disadvantage. To overcome this, rendering of the walls becomes essential. However, in certain situations, high permeability of this type of concrete can be used to good advantage e.g., as drainage layers in soils.

<u>Longer Retention of Formwork</u>- Regardless of the mix proportion and water-cement ratios used, it has little or no cohesion in the fresh state. It is, therefore, essential that formwork be kept in position for a number of hours after casting to allow the cement paste to gain sufficient strength to hold the aggregates in place.

REFERENCES

1. Francis, A.J., "Early Concrete Buildings in Britain", Concrete and construction Engineering (England) V. 60, February 1965, pp. 73-75.

2. Macintosh, R.H., Bolton, J.D., and Muir, C.H.D., "No-Fines Concrete as a Structural Material", Proceedings, The Institution of Civil Engineers, V. 5, 1956, pp. 677-694.

3. Anon., "Draft Bibliography No. 9: Reference to No-Fines Concrete", Building Research Station, Garston, Waterford, (Herts) 1973.

4. Short, A., and W. Kinniburgh, "Lightweight Concrete", 1960, John Wiley and Sons, Inc., New York, N.Y.

5. Giddens, Joseph, J., "No-Fines Concrete", Paper presented at the two-day annual seminar of the Canadian Capital Chapter, ACI, Ottawa, Ontario, Canada, November 29-30, 1972.

6. Simms, L.G., "The Behaviour of No-Fines Concrete Panels as the In-Fill in Reinforced Concrete Frames", Civil Engineering and Public Works Review, Vol. 62, No. 736, November 1967, pp. 1245-1250.

7. Petersen, Perry H., "Properties of a Porous Concrete of Cement and Uniform Sized Gravel", U.S. National Bureau of Standards, Report BMS 96, The Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 1943, 15 pp.

8. Valore, R.C. and Green, W.C., "Air Replaces Sand in No-Fines Concrete", Proceedings, American Concrete Institute, Detroit, V. 47, 1951, pp. 833-846.

9. Anon. "No-Fines Concrete Housing System", Wimpey, Toronto, (Undated brochure issued by the George Wimpey Co.).

10. CSA Standard A 23.4, 1973, "No-Fines Concrete", published by the Canadian Standards Association, Rexdale Boulevard, Rexdale, Ontario, Canada.

11. Anon, "No-Fines Concrete" Portland Cement Association, Johannesburg, 24 pp.

12. Malhotra, V.M., "Mechanical Properties and Freeze-Thaw Resistance of No-Fines Concrete", Mines Branch Investigation Report IR 74-21. Dept. of Energy, Mines and Resources, Ottawa, Canada, April 1974.

13. Anon., "Engineering Developments in the U.S.S.R.", Civil Engineering and Public Works Review, (England) V. 53, No. 621, March 1958, pp. 273-320.

14. Sorensen, C.P., "No-Fines Concrete", Technical Study 37, Commonwealth Experimental Building Station, Sydney, Australia, August, 1952, 36 pp.

15. Sidwell, Harold, "Long-Term Tests on the Strength of No-Fines Concrete", Civil Engineering and Public Works Review, (England), V. 49, No. 579, September 1954, pp. 939-40.

16. Boyd, A.F., "Report on Tests Carried Out on No-Fines Concrete for Compressive, Transverse and Torsional Strength", Duplicated Document, Commonwealth Experimental Building Station, Sydney, December 1946, 6 pp.

17. Malhotra, V. M., "Problems Associated With Determining the Tensile Strength of Concrete", Mines Branch Information Circular, IC 191, 1967, 62 pp.

18. Neville, A.M., "Properties of Concrete", John Wiley and Sons, New York, Inc., 1973.

19. Hope, H.E., "The Use of No-Fines Concrete", Duplicated Document No. 10, Commonwealth Experimental Building Station, Sydney, July 1947, 29 pp. Also Refer to Note No. 8, "No-Fines Concrete" Published by CEBS, October 18, 1950, 4 pp.

20. Report by ACI Committee 116, "Cement and Concrete Terminology", American Concrete Institute Special Publication SP 19, 1967.

21. Ashton, L.A. and Bigmore, R.H., "The Fire-Resistance of No-Fines Concrete Walls", Civil Engineering and Public Works Review, (England), V. 49, No. 576, June 1954, pp. 597-599; V. 49, No. 577, July 1954, pp. 729-731; V. 49, No. 578, August 1959, pp. 941-943.

22. Brown, T.D., and Javaid, M.Y., "The Thermal Conductivity of Fresh Concrete" RILEM, Materiaux et Constructions, V. 3 No. 18, November-December 1970, pp. 411-416.

VMM:ec