Study of exposed reinforced concrete facings

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PREFACE

Precast concrete panels are extensively used in Canadian construction. Recommended practices for the production of this type of exterior wall cladding in European countries are therefore of special interest to the Division. The paper outlines the requirements used in France for concrete materials, panel forms, placing and curing to provide a durable facing. Various techniques are briefly described which enable a range of surface finishes to be obtained.

This translation was prepared by Mr. D.A. Sinclair of the Translations Section of the National Research Council, to whom the Division of Building Research records its thanks.

Ottawa — R.F. Legget

November 1961 — Director

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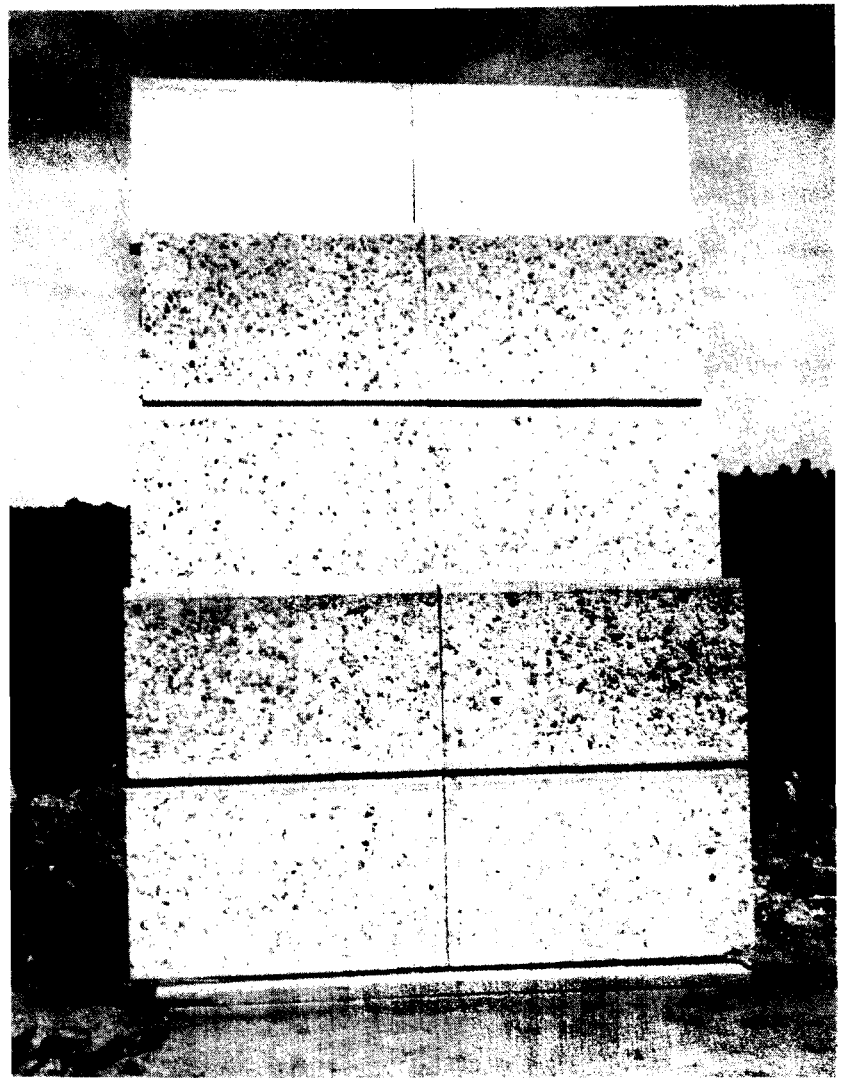
A STUDY OF EXPOSED REINFORCED CONCRETE FACINGS

Summary

The Chambre Syndicale des Constructeurs en Ciment Armé (the Reinforced Concrete Builders' Association) was instructed to draw up, in line with the programme of the International Building Committee, a study on exposed reinforced concrete facings.

To this end the widest possible consultation was undertaken among builders having acquired experience that could be considered authoritative in the field, and numerous tests were made.

The extensive documentation thus accumulated has made it possible to draft the present report which deals successively with generalities as to materials to be used and their placing, then with the various types of facings most currently used in France, together with the materials used, working methods, the advantages and the economic aspect of the processes of execution, and finally with aging behaviour from the point of view of deterioration, cracking, impermeability, soiling and maintenance.



Institut de Recherches Appliquées du Béton Armé (IRABA)
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Tiles kept for laboratory facade facings

Bottom: tiles for the subfoundation (see Fig. 12 and 13)
Centre: tiles for superstructures (Seine aggregates and white cement)
Top: tiles for office storey (Berchères aggregates and white cement)

1. General Considerations on the Quality of the Materials and on Their Employment

1.1. Concrete

In order to obtain a proper facing which does not require retouching; which is always apparent, it is necessary:

to use concretes with aggregates of very uniform grading obtained from a single source;

to use binders of uniform colour, i.e. coming from the same plant and being of the same class and type.

When, for reasons of economy, only a single surface layer a few cm thick constitutes the facing special care has to be taken to avoid any interference with the mass concrete, since this can produce an unsightly effect (Fig. 1).

Any concrete that is to remain visible should be vibrated so as to increase its density and to eliminate air bubbles. The best method appears to be internal vibration, not carried too far in order to avoid segregation. For this purpose one may alternately place and vibrate the concrete uniformly by successive thin layers. If the height of the lift is too great the air is unable to rise and escape (puncturing simultaneously along the formwork facilitates the release of the bubbles).

The use of admixtures and air entrainers is delicate because the mixture is rarely constant and colour variations of a more or less serious nature may arise, depending on the compatibility of the admixtures with certain binders or aggregates, which is not always assured.

The tinting of the concrete by means of dyes contained in the mixing water is difficult to keep constant. It should therefore be applied only to certain separate units such as mullions and transoms. On broad surfaces comparatively pure rain water may cause the lime to separate out from the cement after a time, leaving distinct traces.

White cement gives good, uniform results.

The precautions to be taken after setting must not be neglected (drying out, freezing, etc.)

1.2. Formwork

Formwork must be:

easy to strip (smooth and well protected);

impermeable and rigid; any permeability will result in inhomogeneities at right angles to the joints with leaks of laitance. Absence of rigidity will produce irregularities of surface (Fig. 2).

Coatings applied to the formwork for its protection or to facilitate stripping (oils, varnish, paint, etc.) must not attack the concrete.

1.3. Reinforcements

Reinforcements must be protected by at least:

3 cm of concrete, after treatment, in sheltered zones;

5 to 6 cm concrete after treatment, in exposed zones.

It is very important for the reinforcements near facings to form a fine, close network. This increases the number of possible cracks but reduces their unit width and thus improves the resistance to corrosive agents.

2. Various Types of Facing in Current Use

2.1 Rough-cast facings

(a) Quality of materials and of concrete:

Aggregates: standard; uniform grading.

Maximum size of aggregates limited to e/3 for fine units of thickness e.

Avoid sands that are too coarse.

Binders: be careful with certain contemporary slag cements which are not of uniform shade.

Dosage and water-cement ratio: depends on the placing process and the dimensions of units.

In general 270 to 350 kg/m^3 for standard units; 350 kg/m^3 or more for small units less susceptible to shrinkage cracks.

Enough water to ensure a very plastic concrete.

(b) Placing of the concrete:

In placing one must avoid:

segregations;

the formation of blisters;

unsightly construction joints; for this purpose a careful study of the architecture should enable the builder to make every construction joint coincide with a break in the facade. This important principle has been recommended and supplied by the great advocate of concrete architecture, Auguste Perret (Fig. 3).

It is possible to avoid these disadvantages either by introducing the concrete at the bottom of the formwork or by discharging it at as low a level as possible with the aid of a chute, and in any case by applying thin layers (25 to 30 cm maximum).

There should be careful vibration, especially close to the forms, but not too prolonged and above all regular.

In particular, vibration by means of the forms, when excessively prolonged, produces partial, irregular segregation of the concrete with an excess of laitance close to the forms. This imparts a rather disagreeable marbled appearance to the facing.

Remedy: Remove forms after setting is complete and use a curing treatment depending on the type of binder, especially where slag cements are involved.

(c) Production techniques:

c.1. The formwork may be of metal, concrete, wood or special units.

c.1.1. Metal: smooth appearance.
Blistering, sometimes of a severe character, if the formwork is of light-weight sheet metal. Construction joints and joints between panels visible (Fig. 4).

c.1.2. Concrete: smooth appearance.
Few blisters.
Handsome facings for large horizontal surfaces.

c.1.3. Wood:
Formwork of planking: imprint of grain.
Moderate blistering; the present tendency is to use panels

of assembled planks stiffened by profile irons with fastening holes; this enables the planks to be used over again several times.

Panel formwork: clean surfaces retaining the imprint of the panels.

Blistering inversely proportional to the thickness of the panels (Fig. 5 and 6).

The construction joints are visible, but their appearance can be improved by grooving with the aid of a rail on the inside of the formwork.

The joints between planks or panels must be fairly tight to prevent leaks or laitance.

c.1.4. Special devices:

Forms fitted with backings that leave a desired imprint on the concrete.

Such backings may be of various form, e.g.:

linings of the Formica type: very handsome glazing, on which the smallest blister or surface irregularity is noticeable.

soft linings of the Gerflex type: less glazing effect; permits lining of broad surfaces, but tears easily.

c.2. Forms are generally coated with agents to protect them and facilitate stripping; these products must also:

not stain the concrete nor attack the grouting (as certain oils do);

promote wetting of the formwork by the concrete (avoidance of blistering);

not adhere to the concrete after it has set (some paints do this).

(d) Various advantages:

d.1. Labour: apart from the careful control of the formwork, this procedure is the one which requires the least labour, because after stripping the concrete will need at most only a curing treatment.

Various types of formwork and their applications

Materials	Type		Re-use	Cost	Application	Appearance	Blistering	Precautions	Form
Metal	Light assembled units		50 to 100	Fairly high	Concrete poured on site	Visible, sometimes ugly joints	Frequent blisters	Easily chipped	Simple units
	Heavy monolithic units		100 or more	High	Prefabrication	Very good	Few blisters	Very little maintenance	Any form
Concrete	Heavy monolithic units (bottom of mould)		100 or more	Moderate	Prefabrication, bottom of mould	Very good	Very few blisters	Straight oiling	Can be stripped
Wood	Assembled boards		1 to 20	Variable	Poured on site	Average	Blisters scarcely visible	Variable	Regular surfaces
	Panels	Plywood	15 to 60	Fairly high	All applications	Sometimes poor	Blisters unless rigid	Weak edges requiring reinforcement	Flat
		Fibre board	1 to 50	Variable	do.	do. Grainy or smooth		Require rigid supports; frequent oiling	Possible deflections
Special units	Rigid		50 to 200	High	All	Very neat, care with joints	Few blisters very visible	Breakable	Flat
	Soft		5 to 20	High	Large complex surfaces	Avoidance of joints, fine appearance	A few blisters	Fragile, subject to tearing	Developable surfaces

d.2. Quality and appearance:

With these methods the concrete not only retains its skin, but is not subjected at a relatively young age to various mechanical treatments which may disrupt it on the surface, frequently start cracks and destroy the zone of the concrete which is particularly impermeable, namely the skin.

The appearance depends on the kind of formwork used and varies greatly.

(e) Aging

Aging is generally very uniform. Irregularities of appearance are generally due to the local trickling of rainwater down the facade. This is primarily an architectural problem.

However, rough-cast facings provide a continuous veneer which may emphasize variations of hue or stains, but which is easy to clean.

Cracks can be localized by the provision of lines of least resistance and by limiting the dimensions of the units, since cracks on a flat facing are always unsightly.

2.2. Facings of Visible Aggregate

2.2.1. Washing (Fig. 7 and 9)

(a) Quality of materials and of concrete:

Aggregates: diameter less than 12 mm in continuous grading. Discontinuous grading, edge 18/22 mm, for example.

Preferably rounded aggregates (crushed aggregates are unseated by the brushing process).

Choose the mixture and colour with taste.

Binders: transparent binders preferred.

Mixture: continuous grading; moderate concentration; discontinuous grading; high concentration.

Pasty consistency.

(b) Concreting process:

Generally used in prefabrication where only a single surface layer is of concrete specially made for this purpose. It is bonded to the rest of the structure by vibration (which permits an

interpenetration of the various layers).

(c) Production technique:

If the face to be washed is at the bottom of the mould the unit is turned over for treatment. In the opposite case the unit is slightly inclined.

The treatment is carried out about one hour after the units have been made, or, if a setting retarder has been used, 24 to 36 hours later.

The water is first sprayed on gently, then in a jet over the face, which is inclined 5% or 20% on the washing bench while at the same time the unit is worked over with a soft brush.

No puddles must remain after washing. These form milky films on drying which are difficult to clean off.

Cleaning takes place one or two days afterwards with dilute hydrochloric acid. This is followed by rinsing freely with water.

(d) Various advantages:

The process is more popular in prefabrication because fairly precise time intervals have to be observed if it is to be successful and the operation must not be pushed too far for fear of dislodging the pebbles.

The concrete continues setting after the treatment. This does not affect the mass and therefore the latter retains its impermeability and mechanical strength properties.

The appearance, which depends on the pebbles, is agreeable.

The cost of the shop operation is low, provided the process is properly executed.

(e) Aging, maintenance:

The washed units age well and uniformly. Their variegated appearance counteracts staining and the slight mechanical attack of the surface due to the treatment facilitates cleaning.

2.2.2. Inlaid aggregates

A kind of mosaic, the appearance of which depends essentially on the artistic talent of the architect who selects the gravels, pebbles, pieces of glass, etc. and on the artisan who applies them.

(a) Quality of materials - concretes:

Standard concrete is used. The inlaid elements are selected.

(b) Placing, treatment:

b.1. In prefabrication: The selected elements are placed at the bottom of the bare mould, or better, on a layer of sand. The concrete is then poured on top. Finally, after stripping, the sand is washed or brushed off (Fig. 8, 9 and 16).

b.2. For concrete poured on the site the so-called transfer method can be used. The aggregates are first glued to the formwork panels with a water-soluble glue and fine sand is then added. After stripping the inlaid elements remain embedded in the concrete and can be brought up by brushing.

(c) Various advantages:

Does not reduce the quality of the concrete (impermeability, etc.), appearance sometimes very handsome.

Cost, varies greatly.

(d) Aging, maintenance:

Aging depends on the kind of elements inlaid. Washing is generally easy.

Some of the elements may become dislodged and this will impair the appearance of the facing greatly.

2.2.3. Granulating (Fig. 2 and 10)

(a) Quality of materials and of concrete:

Aggregates: concrete with minimum sand; continuous grading; best results with pebbles. Avoid materials of excessive hardness.

Binders: types in common use.

Mixture: standard.

(b) Placing and treatment of the concrete:

Construction joints to be made with extreme care using a slightly more plastic concrete than for the whole; vibrate energetically (do not count on the roughening to disguise segregation faults or discontinuities at the joints).

Reinforcements should be placed at least 3 to 5 cm from the finished facing.

(c) Production technique:

Granulate over 5 mm, use 16-toothed or 25-toothed hammer; finish with a 49-toothed or 64-toothed hammer.

Do not granulate until the concrete is thoroughly hardened.

Do not granulate ribs; leave a rough-cast listel (it is not advisable to carry on the listels with built up mortar - chipping, flaking, etc.).

(d) Various advantages and disadvantages:

Handsome appearance when the concrete is very uniform.

Concrete subjected to severe mechanical treatment which may start cracks, cause permeability and corrosion of reinforcements.

An expensive and somewhat slow process (concrete must be hard).

Generally applied to concrete already installed.

Sometimes a subsequent sand-blasting is needed.

(e) Aging, maintenance:

Ages well - difficult to wash - deteriorations due to permeability resulting from repeated hammer blows.

2.2.4. Sand-blasting (Fig. 12, 13 and photograph on page 4)

(a) Quality of materials and of concrete:

Cf. Sec. 2.2.3. (a) (pebbly or crushed-stone aggregates).

(b) Pouring of concrete, treatment:

Cf. Sec. 2.2.3. (b) for concrete on site. However, this method is more popular in prefabrication where the sand can be recycled. In this case the concrete must be blasted very uniformly.

(c) Production technique:

Blasting is carried out when the concrete has barely hardened.

Thus, if it is poured in the morning, it will be blasted that evening. The blasting is done gently so as not to spoil the polish of the stones. It should not be accomplished by washing, which might dislodge the stones (Fig. 11).

(d) Various advantages:

Mechanical attack on the concrete is slight.

A rapid shop operation, but one requiring a certain care in the observance of time intervals and the duration of blasting.

Moderate cost by industrial standards.

(e) Aging:

Good aging, easy maintenance if blasting has not been overdone.

2.2.5. Pumicing (Fig. 14, 15 and 16)

(a) and (b)

Cf. Sec. 2.2.3. and 2.2.4. (a) and (b).

The aggregates must be chosen so as to give a fine, polished surface (basalts, marbles, porphyries, Loire stone, Ecuelles gravels, etc.).

(c) Production technique:

First regular granulating, then smoothing with the 100-toothed hammer, and finally pumicing.

(d) Various advantages and disadvantages:

Very handsome facing when successful.

Very costly process.

Cracks occur easily; it is therefore best to treat only rather small units which are subject to little stress.

(e) Aging, maintenance:

Aging depends on the aggregates chosen, but the latter can be polished with pumice periodically.

Very easy to wash.

2.3 Prefabricated tile facings

Prefabricated tile, in their turn, can be used either as forms incorporated in a concrete wall or as facings applied to a wall already constructed.

Obviously, any type of prefabricated tiles can be used for this purpose, e.g. cut stone or reconstituted stone (especially of rock dust) or panels of wood or metal, although the latter do not come within the scope of the present study, unless the concrete is visible.

True concrete tiles are generally of small size to permit easy handling and are slightly reinforced to prevent damage in transit.

The choice of component materials and manufacturing processes obviously depends on the surface treatment intended, as selected by

the architect from the various processes described above.

The side opposite the facing, which must hold the tile to its support, is often the subject of special study by the builder. As a consequence there are many more or less ingenious methods and patents in existence, ranging from simple grooving of the surface to very complex anchoring devices.

2.3.1. Prefabricated tiles in incorporated forms (photograph on page 4)

(a, b and c) Quality of materials, treatment, production

Cf. above the sections corresponding to the techniques employed.

(b) Placing of tiles:

This is a delicate operation but must be carried out in a very steady, perfectly regulated manner, since these tiles will appear on the facade exactly as they are after the concrete placed on the site has set.

It is wise to provide fibres on the rear face which will be immersed in the concrete placed at the site and to roughen this face so as to obtain a good concrete joint. Since the joints between the tiles are not by themselves tight it is advisable either to place the tiles on a mortar bath or to wash their surfaces as soon as the supports are withdrawn.

(d) Various characteristics:

Facing of high quality and uniform appearance.

Cracks occurring in the skeleton of the building rarely break through the tiles. They may, however, twist them, owing to the comparatively small dimensions of the tiles.

Fragility (danger of chipping at the edges during installation).

Danger of displacement during vibration of the concrete placed at the site. This is impossible to correct subsequently.

High cost, but of interest nevertheless, having regard to the surface treatment employed by reason of the fact of shop production.

(e) Aging, maintenance:

Depends on the type of facing chosen. Appearance almost always remains satisfactory and uniform over the years owing to the greater

constancy of shop-processed facings.

2.3.2. Prefabricated tiles applied to the building concrete

(a, b and c) Cf. above, Sec. 2.3.1.

(b') Installation of tiles:

Installation is simple; it is merely necessary to leave holes in the wall for adhesives or anchoring devices.

(d) Various characteristics:

Facings of high quality and constant appearance.

The effectiveness of control over the installation on a finished wall will generally depend on the extent to which the mass work is completed and all the settlement and cracking has become stabilized.

Fragility is often greater than in 2.3.1. owing to absence of monolithism with the wall.

Cost not excessive for very fine facings.

(e) Aging, maintenance:

Cf. Sec. 2.3.1. (e).

2.4. Coatings

The concrete may be coated by:

stucco;

tiling, terra cotta, freestone, mosaic;

plastic coatings: applied by brushing or spraying;

paints, varnishes.

We are not concerned with these types of coating here because they do not come within the scope of this study, which is limited strictly to facings of visible concrete.

3. General Considerations on Aging Ability

3.1. Deterioration

Deterioration of the concrete (apart from cases of abnormal use of the structure) is generally due to:

poor compaction, resulting in a porous concrete;

reinforcements being in more or less direct contact with the atmosphere;

excessive cracking due to shrinkage (units too large or excessive dosage).

Finally, any mechanical treatment of the facing will result in a predisposition to cracking (granulating, sand-blasting, etc.).

3.2. Stains

These are due basically to rain in a contaminated atmosphere, especially where trickling is localized along a facade.

On smooth facings (rough-cast or pumiced) stains show up more clearly, but are easier to wash off.

The rugged facings, especially the sand-blasted and washed ones, seem to disperse the dirt and to mitigate its unsightliness by reason of the variegated background of stones.

Thus, considering only the appearance in assessing the aging ability of a concrete, the best facings appear to be the rough-cast for all cases, and washed or sand-blasted ones for units of small dimensions.

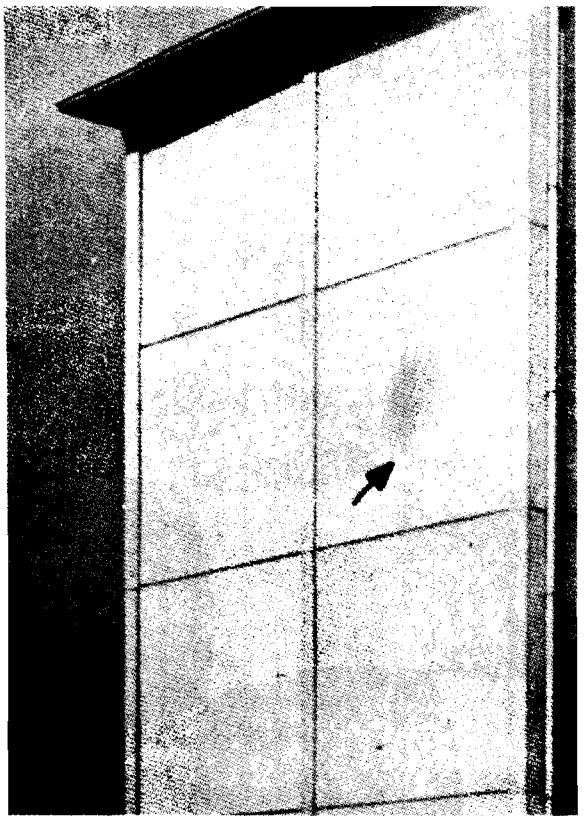

Fig. 1

Gable tiles, prefabricated flat

First a few centimetres of white cement facing concrete are placed at the bottom of the mould. Reinforcements are then put in position and the tiles are built up to full thickness by placing ordinary concrete. Carelessness in execution of the right centre tile resulted in the unsightly spot

Fig. 2

Facing of granulated concrete placed in forms consisting of planks laid side by side. The concrete has lost its fine constituents at right angles to the joints between planks, whence the lines which granulating could not erase

Fig. 3

Construction joint defect in a granulated concrete

This fault will always remain visible no matter what process is used. Thus, concrete construction joints should always be made to coincide with a surface discontinuity of the structure

Fig. 4

Circular column placed in 2 mm sheet metal formwork

This kind of formwork always brings out joints and blisters as well as faults of alignment between forms

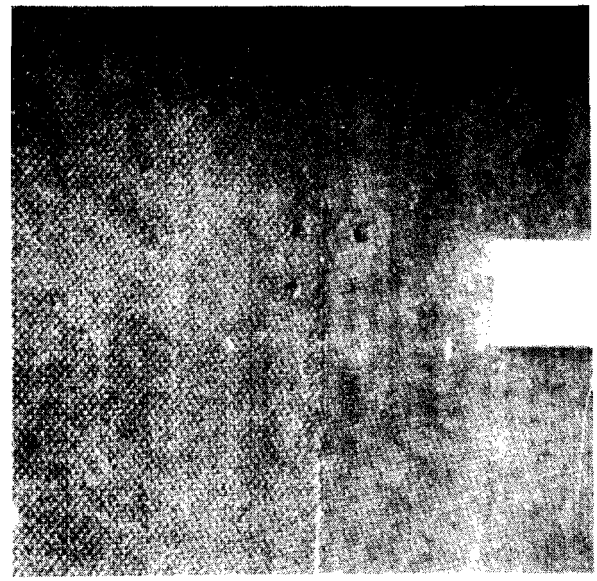

Fig. 5

Wood fibre formwork, grill surface

Detail: Note the excellent quality of the concrete at right angles to the joint, the complete absence of blisters and the marks left by the fastening points of the panels which, in this case, were not glued to their support

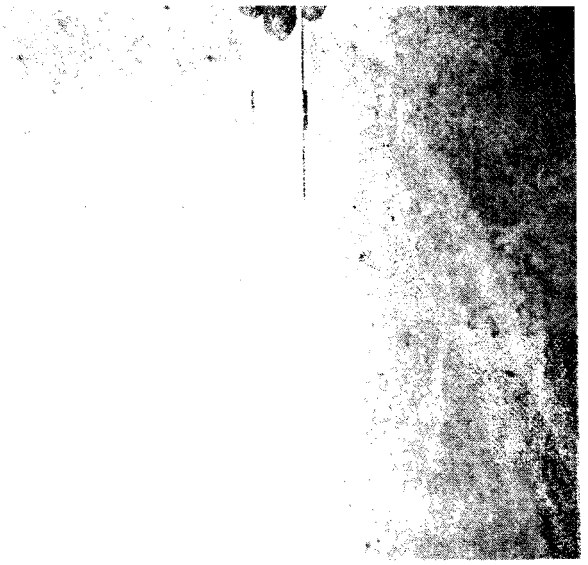

Fig. 6

Cylindrical fibre-board formwork with a radius of 1 m; smooth surface

Note the excellent appearance of the joint at right angles to which the quality of the concrete is fully maintained

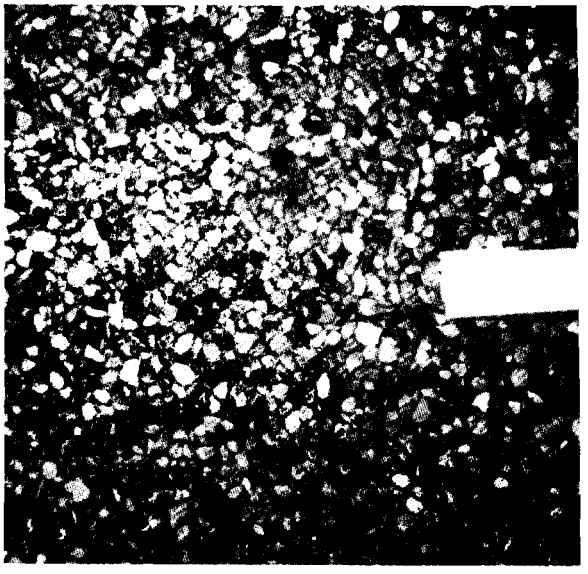

Fig. 7

Facing of washed tile, pebbly aggregate of the Paris region called "rice grains" (prefabricated)

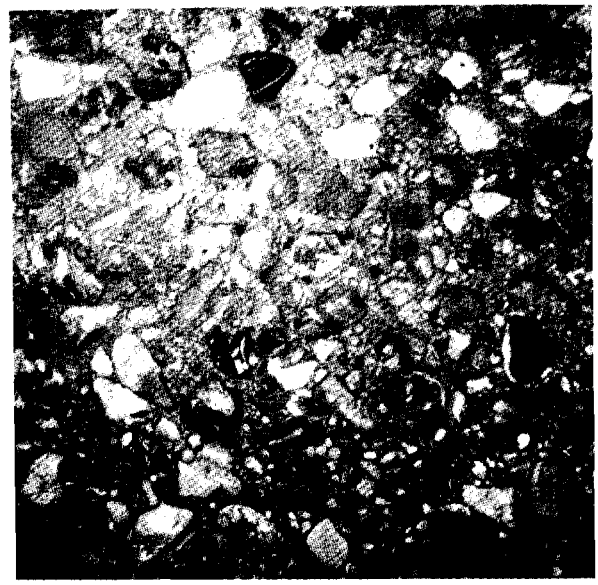

Fig. 8

IRABA. Study for facade facing

Facing of sand-blasted concrete with coarse Seine aggregates (40-60) arranged initially at the bottom of the mould (built up aggregates)

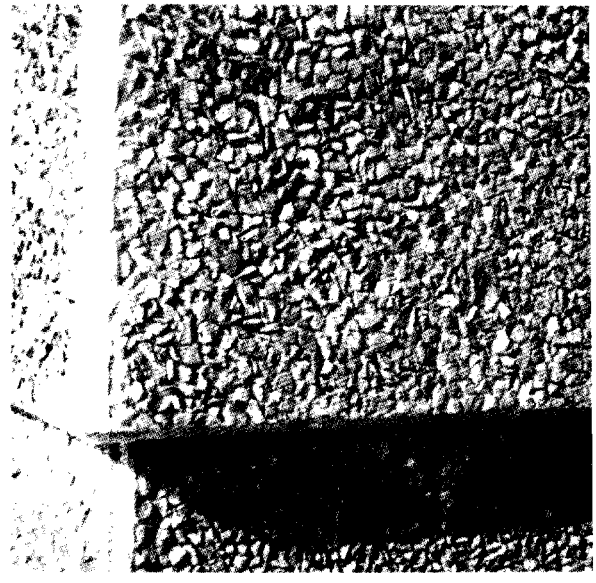

Fig. 9

Tiles in a facing of built up aggregates,
porphyry broken to 4 - 7 cm sizes (prefabricated and washed)

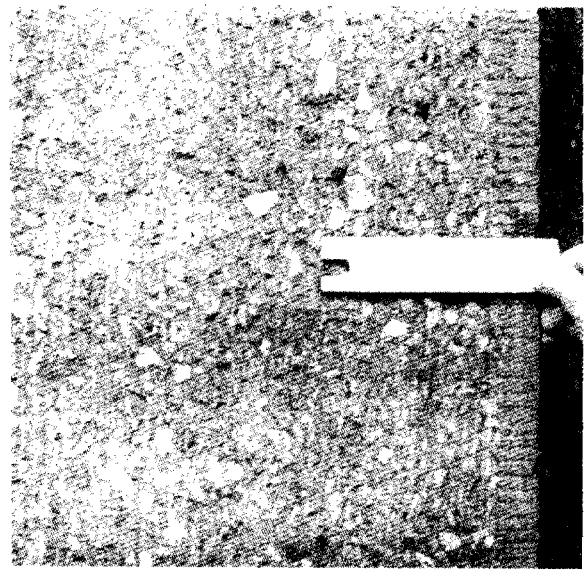

Fig. 10

Concrete granulated and washed on site.
Seine aggregates

Fig. 11

IRABA. Prefabricated tiles for the hall facade

Sand-blasting on concretes 16 to 24 hours old

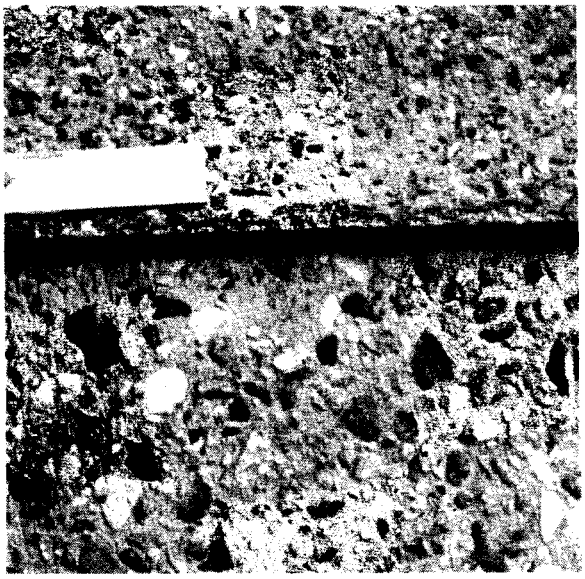

Fig. 12

IRABA. Cornice around the terrace reserved for the production of large units

Upper part: sand-blasted topping concrete produced on site.
Lower part: prefabricated tile, sand-blasted and used in lost form (see Fig. 11 and 13).

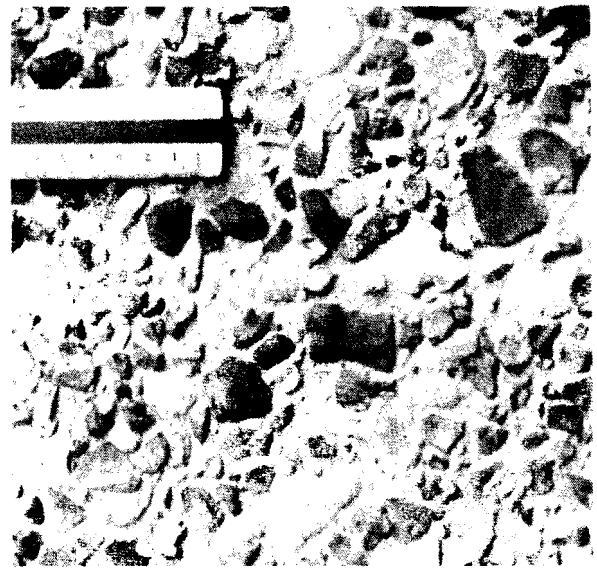

Fig. 13

IRABA. Detail of a prefabricated facade tile

Seine aggregates 10-40 and Portland cement 210-325. Very careful grading, sloped as in the moulds and sand-blasted the day after placing

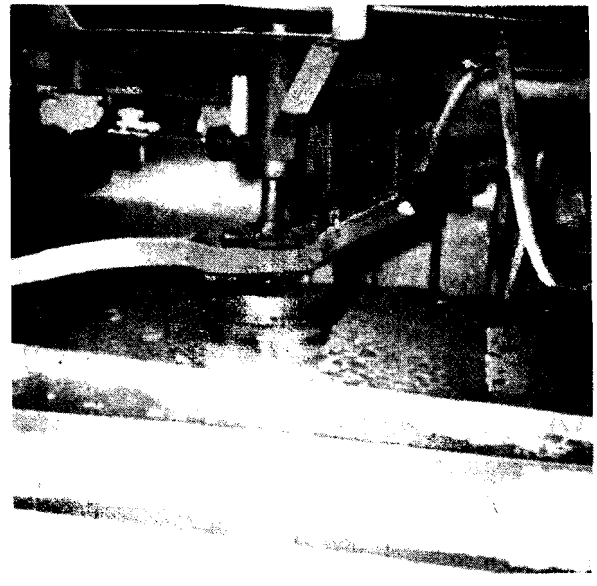

Fig. 14

IRABA. Study for interior facing of visitors' entrance

Pumicing of prefabricated tiles

Fig. 15

IRABA. Pumiced tile made from silex gravel 10 - 20 Ecuelles sand and white cement

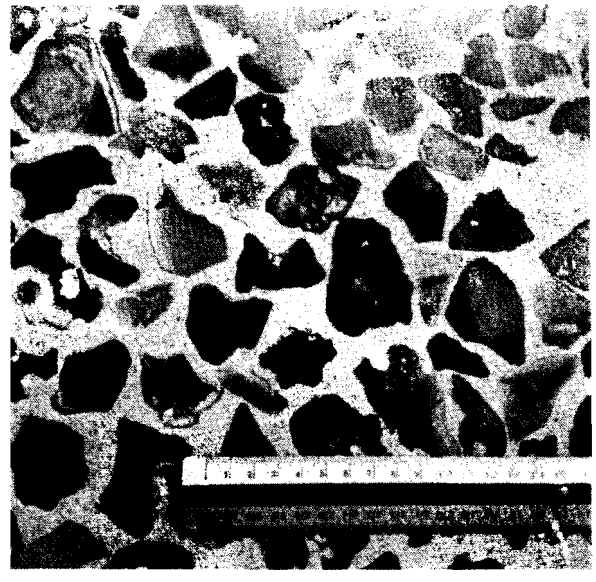

Fig. 16

IRABA. Prefabricated pumiced tile with silex gravel 20 - 40 placed at the bottom of the mould and Ecuelles mortar sand with white cement