Construction of concrete floors[1]

By Herbert K. Cook[2]

Concrete floors are used for a great variety of purposes and are subjected to an equal variety of abuses, both during and after construction.

One of the most familiar types of concrete floors to all of us is probably the garage, basement, or floor slab directly on the ground, in our own homes. Because it is so familiar and so deceptively simple to construct, it is probable that this type of floor is more abused during construction than any other. A too common procedure for making a residential type floor level is to build it like a skating rink: flood the concrete in the mixer with water so that it will be self-leveling. The not unexpected result can best be illustrated by a story that is alleged to be true:

A ready mixed concrete producer received a phone call from a housewife who had just moved into a new home. She said she thought she had a complaint about the concrete in the basement floor. The producer asked what the complaint was. The housewife said that her dog had just dug a hole in the concrete floor and buried a bone; while she wasn't sure, she did think that the floor was not all it should be.

Regardless of who is responsible, such incidents do not help the concrete construction industry. While the incident is quite unusual, each of us knows of some poor quality residential concrete. Unless we are more fortunate than most, we probably have such areas somewhere around our own homes.

From the relatively simple residential slab on the ground, we move to the more complicated warehouse and industrial type floors which can include floors with no more stringent requirements than a home garage up to such highly specialized floors as are required for steel mills, or even more highly specialized safety floors which are required for hazardous areas used in connection with the manufacture of munitions or volatile solvents where the floors must not only be structurally sound and abrasion resistant but must also be conductive, spark-resistant and static-disseminating. This discussion will attempt to cover some of the things which all of these floors have in common and suggest some of the things which will help to insure that they perform as intended.

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A fairly recent nationwide survey indicated that 61 percent of industrial concrete floors have caused trouble. Another survey ranked floors as the third most troublesome item in new construction. Certainly this is an area where there is great room for improvement.

Fortunately good concrete floors can be constructed with a minimum increase in cost and effort. Considering the cost of replacing an unsatisfactory concrete floor, taking the trouble to construct it properly in the first place is the cheapest insurance in the world.

For those of you who may want to study the matter further, particularly residential floors, two excellent references are the publication of American Concrete Institute Committee 332, "Guide for Construction of Concrete Floors on Grade," which was published in the October, 1962, Journal of the American Concrete Institute; and National Academy of Sciences, Publication 657, "Design Criteria for Residential Slabs-on-Ground." The latter was a technical study for the Federal Housing Administration done by the Building Research Advisory Board in 1959 and costs $2.00 per copy. The National Academy of Sciences publication covers all of the details of constructing a concrete slab on ground from site preparation, soil treatment, climatic considerations, concrete design and control, and the structural design of several types of slabs for various ground conditions.

Both of these references have been drawn on for this discussion. Mention should also be made of the work of the American Concrete Institute Committee 302 on Concrete Floor Finishes. Although established only fairly recently, this committee contemplates issuing a recommended practice for several varieties of concrete floor finishes within the next few years. The Portland Cement Association has also published excellent treatises on floors.

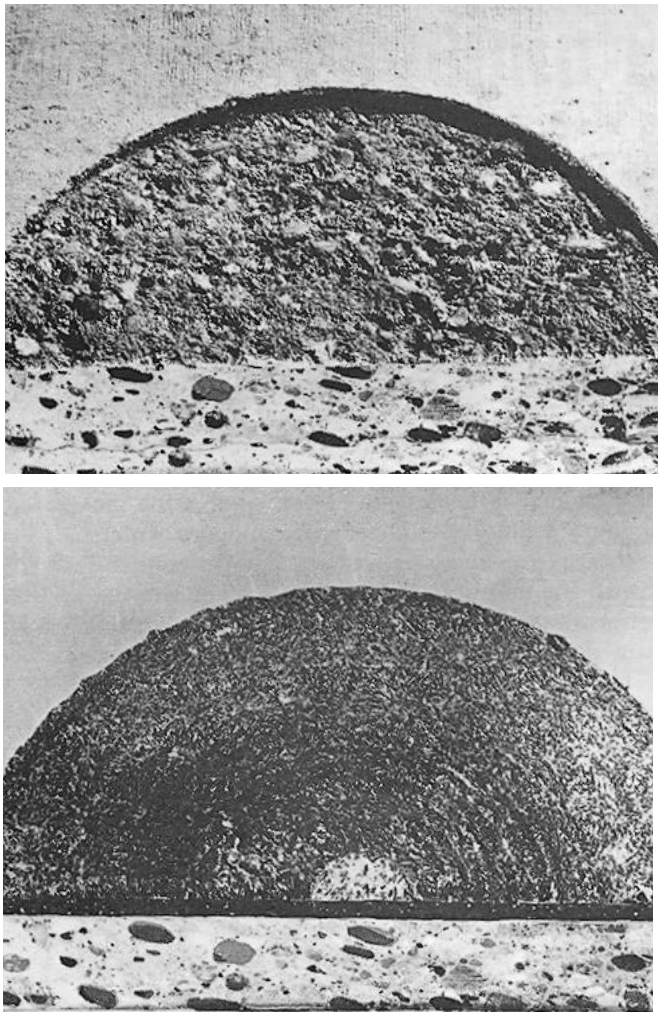
No particular distinction can or should be made in concrete mix proportions and properties between a concrete floor for a residence and one for an industrial operation. Of course, a heavily loaded industrial floor may require considerably greater thickness, more reinforcing and most probably a special wearing surface. However, there is no reason why both floors should not be constructed of high quality, high strength concrete. Even in low cost housing there should be no tolerance for poor quality, low strength concrete in a floor. Perhaps it is all right to use slop as fill in a crawl space, but this discussion is concerned with floors and areas used as floors which will at least be walked on. The installation of poor quality concrete in a floor is not an economy even for the contractor.

No floor slab should be less than 4 inches thick. How much thicker it should be depends on its location, climatic conditions and structural requirements.

For a slab on ground the first requirement is a site with good drainage or one for which drainage is otherwise provided. Many a good slab has come undone because of poor drainage.

Site clearing and preparation should be performed in such a manner as to satisfy structural requirements of the type of floor slab to be constructed and for the building.

Organic matter, such as roots and grass, should be removed and any trenches, large holes, or other irregularities in the subgrade should be filled and well-compacted in 6-inch layers. Granular fill with gravel, crushed stone or slag is desirable in bringing the site to uniform bearing and grade. Special soil conditions should be taken care of as appropriate; in some instances this may require removal of a foot or more of the existing material and replacement with granular fill.



These two slabs of concrete have been subjected to the Bureau of Standards floor abrasion test for the same period of time. The deeply worn specimen at the top is ordinary concrete. The specimen at the bottom has resisted abrasion because of the use of a metallic aggregate on the surface.

Usually it is practicable and desirable to provide a fill of clean granular material over subgrades of clay or cohesive soil for the purpose of providing a capillary deterrent, and to provide space for expansion of subsoil. The granular material should be retained on a No. 4 screen and the fill should have a minimum depth of 4 inches.

Proper site and subgrade preparation can help greatly in reducing settlement cracking and wet floors, which can occur in even high quality concrete if these things are not properly attended to.

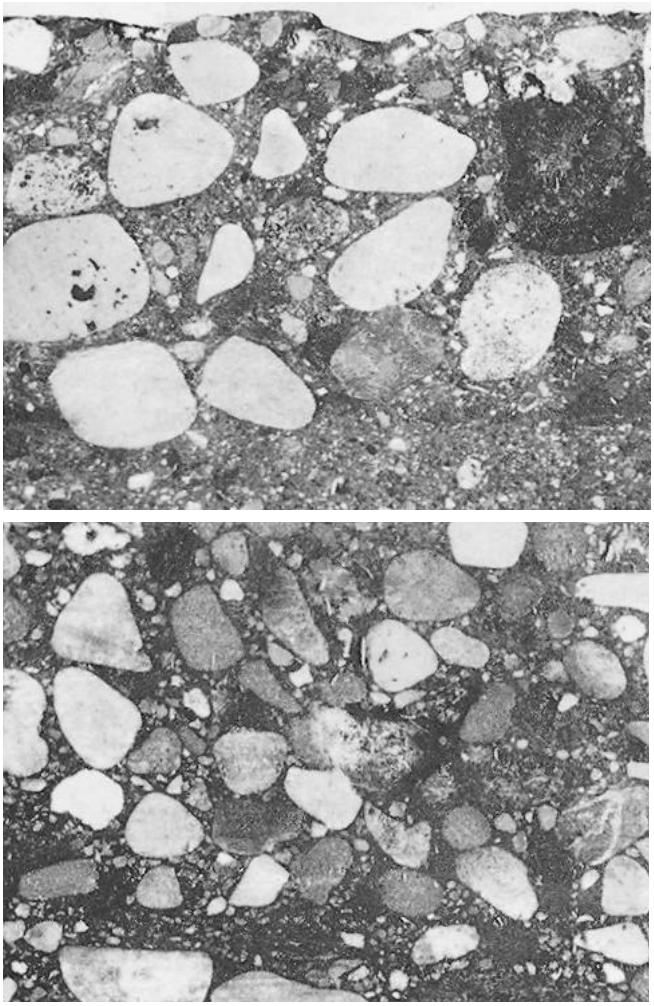
The materials used in the concrete obviously should be of good quality meeting ASTM or other applicable specifications. With respect to the quality of the concrete itself, there may be room for some disagreement with ACI Committee 332 which calls for 3,500 psi concrete for structural adequacy and permits lower strengths for nonstructural floors. This would be acceptable if a good topping mix is used over the base slab, but concrete with any less than 3,500 psi, and preferably 4,000 psi, should not be used in any floor constructed in a single course operation. It just will not have enough abrasion resistance and will not be non-dusting. Assuming the use of sound, hard aggregates, concrete floors to be covered with some other material, such as tile or carpeting, can be built satisfactorily with a 3,000 to 3,500 psi mix. By this, however, is meant a floor with concrete surfaces of 3,000 to 3,500 psi. Often the concrete bleeds to such an extent that fines and laitance are brought to the top of the slab and the water/cement ratio at the surface is increased greatly. The result is a floor in which the weakest concrete is at the surface—precisely where it must bear the greatest wear. The result is a weak, dusting surface. Because the slab will be permeable, water seepage can cause tiles to curl and become detached, and of course can ruin carpeting. Concrete for floors must be such that bleeding will be minimized and that it will develop proper strength.

Bleeding can be minimized in several ways. One obvious approach is to use the least possible mixing water and place the concrete at as low a slump as possible. The amount of mixing water can be further reduced through the use of proven water-reducing admixtures; these will also increase the strength of the concrete 10 to 20 percent at an increase in cost of only 2 to 3 percent.

Bleeding can be further reduced by air entrainment, but the optimum amount of air will depend on climatic exposure. For exterior floors exposed to ice and snow, the recommended amount of air entrainment is from 5 to 7 percent. This concrete should be float finished, not hard-troweled. The optimum air content for interior floors is about 3 percent. At this percentage, strength is maximum and the surface may be hard-troweled without difficulty from blisters. Minimized bleeding and blistering tendencies are particularly important if a dust-on treatment is to be used.

Floors that are to be exposed and subjected to foot and/or truck traffic should have concrete of 4,500 to 7,000 psi strength on the wearing surface. While abrasion resistance increases with increases in compressive strength, a highly important fact to remember in the construction of concrete floors is that it is the aggregate that must withstand the bulk of the wear and tear of the traffic. Even very high compressive strength cement paste has relatively poor resistance to abrasion. It is the aggregate which lies at the surface of the floor that absorbs impact and resists abrasion.

If your floor is to experience only light foot traffic or occasional pneumatic-tired hand trucks, a well-washed, graded, sound quartz or crystalline granite aggregate bound by a strong cement paste will often suffice, granting proper construction procedures including proper curing. Frequently, however, conventional aggregates simply are not economical for floors. Although offering some penny savings in first cost, they soon tip the scales heavily in the other direction as the need for retopping or tearing out and recasting arises.



Cut sections through two different gravel concrete floors subject to about the same wear over the same period of time. The deeply worn, uneven surface of the concrete (top photo) is the result of a concentration of fine sand and gravel at the surface. There is no visible wear in the concrete section below because the wearing surface is composed mainly of coarse, evenly matched aggregate.

A number of specially quarried or manufactured aggregates are on the market today, including emery, trap rock and those made from ferrous materials. Trap rock and emery offer good abrasion resistance but leave something to be desired in impact strength. When traffic is to be mainly pedestrian they will usually prove to be quite satisfactory. If hard wheeled or heavy vehicular traffic is expected, however, a crushed iron aggregate specially manufactured for such service will provide considerably greater wear resistance. These materials are usually applied as a shake or dust-on which is worked into the surface of the concrete, or as the aggregate component of a topping mix.

In connection with choice of aggregate comes the matter of delineating the floor areas in which it is to be used. This aspect of floor design might seem relatively simple at first glance. But in this age of space flexibility, today's office area might very well be tomorrow's manufacturing area. When deciding the type of floor for any particular area in a proposed building, it would be wise to consider the long-term expansion possibilities as well as the initial floor layout.

As you would engage an air conditioning consultant or an electrical engineer for those aspects of your plans, just as surely an expert on floors should be called in to advise on the type of construction needed to satisfy the various floor needs of the plant being designed. Continually in use and continually in sight, floors speak eloquently of the care and knowledge expended on them by their designers and builders.

In addition to the usual desirable concrete construction practices (many of which take on increased importance in casting floors), and the few special ones already touched upon, there are some additional points that should be heeded.

Joints in floor construction are an art to themselves. As in every art, there are differences of opinion regarding joints and healthy discussion centered about certain points. Even questions of terminology, such as the precise meaning of control, isolation and construction joints, are not always easy to resolve. But fortunately there are areas of agreement; for example, it is widely accepted that it is advisable to use isolation joints to separate floor slabs from walls, footings and columns and from slabs of different thicknesses or shapes to avoid random cracking at these points. Large slabs would be divided by contraction joints into 20- to 25-foot squares to assure controlled cracking in these joints. If random cracking occurs, the cracks will soon spall to impair seriously the performance of the floor.

Concrete of a special consistency is needed to produce a good floor, and this can't always be fully determined with a slump cone. Experienced contractors can tell a good floor mix by its "feel." It will be workable enough to finish easily but it will be stiff enough to

prevent segregation and bleeding. The latter point is especially important in floor work because tough aggregates are needed at the surface for abrasion resistance. For this same reason, overtroweling or too-early troweling is a particularly bad practice in floor construction. Curing of floors should begin as soon as they have stiffened enough to support the paper, matting or whatever is used for curing, and it should continue for at least four days and preferably for a week. This is highly important in preventing dusting, damage from acid attack, aggregate pull-out, and strength loss of as much as 50 percent.

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