Wood Versus Substitutes
In House Construction
by
Dale Harvey

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INTRODUCTION

In the last ten years the government and the people have awakened to the fact that housing conditions are very bad among the low income families of the United States. Consequently, in the early thirties the government launched a program to better housing conditions; which would also stimulate general business conditions for the housing industry, which was a 1,500,000,000 business in 1939, effects a great number of industries.

To carry out this housing program the government installed the Federal Housing Act which was to stimulate construction by making it possible for home builders to borrow money at low rates of interest for long periods of time. The government also attempted to improve housing conditions by building many houses, principally in the slum districts of the larger cities.

The F.H.A. has been a success up to the present time for it has been largely responsible for the increase in house construction the last few years. However, in most instances the slum clearance projects have failed because the houses that have been erected are too costly for low income families.

Although, the F.H.A. has increased house construction, it has for the most part stimulated building only among the families in the middle income bracket. Which means that those families who need rehousing the most are not being aided by the F.H.A. It is estimated at the present time that 2,000,000 new houses are needed. 500,000 of these houses are needed for families on relief or who cannot afford houses. The others are needed for people who can pay from $16 to $30 a month for rent.
Therefore, the problem confronting the housing authorities is how to lower the cost of houses and still maintain a decent standard. There are two solutions to this problem. One is to decrease labor costs by the prefabrication of houses. The other is the selection of materials that go into the home. It is with this second phase that this thesis is concerned.

Wood is one of the most universally used building materials and here in the United States one of the cheaper of the building materials. Because of this cheapness, there is a tendency to believe that the higher priced materials are superior to wood. Consequently, an attempt is made in this thesis to compare wood with the other more important materials that go into the construction of a house as to those factors that are the most important in a building material. Correct methods of construction are also discussed, mostly in relation to frame construction for wood has often been subjected to criticism because of its failure to live up to the builders expectations. It has usually been found that the wood has failed either because of unsound construction or because it has been used in a place where it should not be used.

This study is broken up into the four separate divisions that a house naturally falls into. That is: Foundation, framework and exterior walls, interior walls, floor and trim, and roofing.
There is a saying that a house is no stronger than its foundation. Consequently, a home builder should give a great deal of consideration to the foundation of his house. The importance of a good foundation is illustrated by listing a few results of a defective foundation. Cracked plaster, stucco, and other types of masonry, sloping and warped floors, and jammed doors and windows are often the result of a poor foundation. The requirements of a good foundation are durability in relation to rots, insects, and disintegration from weathering; and it must be capable of holding up the load assigned to it without any weakening that might cause movement. Concrete, brick, and stone come nearest to fulfilling these requirements with concrete being the most common.

The type of foundations that are used in house construction vary as to whether the house is to be a temporary or permanent structure and as to the amount of money the homebuilder wishes to put into the foundation. The most expensive and best foundation is of course the use of the basement walls as the foundation of the house. Probably equally as good if constructed as well is the concrete or masonry foundation that is constructed the same as the cellar walls but is only embedded in the ground deep enough to get below the frost line. If the home builder cannot afford the extra cost of a basement this is the best foundation for all houses of a permanent nature. For houses that are of a temporary nature the foundations may consist of wood, stone, or concrete blocks set upon the ground with the sills of the house resting upon them.
The selection of a certain type of foundation doesn't always end the foundation problem because foundations must be built of good grade materials and be constructed correctly in order to give satisfactory service. Correct foundation construction begins with concrete footing placed to run continuous with the outside walls. Footings should be at least 18 inches wide, 10 inches deep and the top surface exactly level. Where basements occur, footings should project at least 6 inches from the vertical line on both sides. For concrete walls, Portland cement should be used at 1 to 3 of sand and 5 of stone. For brick or stone walls enough Portland cement should be used in the mortar to avoid disintegration under extreme moisture. In reference to wood frame buildings, foundation bolts of at least ½ inches diameter and should be placed at intervals of 6 to 8 feet throughout the circuit of the outside wall, but always at each corner. These should be sunk to a depth of 18 inches minimum, with the threaded end protruding above the top surface high enough to extend through the thickness of the wood sills. When the concrete or cement mortar has set the metal termite shield should be placed in position. Then followed with the sills which are bored to fit over the bolts and then fastened with nuts screwed down tightly. By this method, foundation and sills become one unit and provide proper anchorage for the entire house. This anchoring of the house is extremely important in places where strong winds prevail. This anchorage may also be brought about by embedding the sill in the mortar in the top of the foundation.
The metal termite shield is the cheapest way of preventing termites from gaining access to any wood in the structure. In those houses where there is not a solid masonry wall between the ground and the woodwork of the building all lower members such as sills, joists, and subflooring should be treated with a solution that is poisonous to the termites. Zinc chloride and creosote are the most common solutions used for treating these members. Both these substances are not only poisonous to termites but are wood preservatives as well. As to which is the best to use is dependent upon the conditions surrounding the wood in the place where it is going to be used. The creosote has the advantage over zinc chloride in that it has higher resistance to leaching when coming in contact with moisture. However, creosote has an odor that may be a disadvantage in some parts of the house and cannot be painted over. Whereas, zinc chloride is odorless, can be painted over and is partially fire resistant. Consequently, creosote treatment should be used for those members that touch the ground or are likely to be in contact with moisture a great deal and zinc chloride can be used for treating the rest of the wood.

The Committee on Wood Utilization of the U.S. Dept. of Commerce chose a typical home and estimated the comparative cost of building with treated and untreated lumber. Their findings show that with a 2% increase in cost, all vulnerable parts of a new house can be properly protected against insects and decay. Therefore, the prospective home builder should not have any worries about his house of wood tumbling down about his ears, as is often pictured, due to the attacks of decay.
and termites; if he takes the above cheap and simple precautions when constructing his house.
FRAMEWORK AND EXTERIOR WALLS

Since the walls of a house make up the larger part of a house in area, cost, and appearance, the biggest decision that a home builder must make is the type of walls he wants. The interior walls can usually be changed without too great an expense if the owner tires of them but the exterior walls and framework are not so easily changed. Consequently, before making the final decision the prospective builder should give each type of wall material careful consideration. However, this final decision is constantly becoming more difficult to make because there are not only new materials being introduced but all the building materials are being continually improved.

Wood, steel, and masonry are the three general types of wall construction. The weight that the prospective builder puts upon the following factors: Original cost, durability, appearance, insulation, maintenance, fire resistance, ease of alteration, insurance cost, and strength against wind and earthquake will determine which of the above wall types will be selected.

The average builder has usually determined which of these factors he considers the most important and plans accordingly, but he is handicapped in not knowing which wall type has the qualities he desires. For example a man in a cold climate with a small annual income would probably emphasize cheapness and insulation but would not know which wall type would give it to him.
In order to eliminate any confusion that might exist as to the different wall types, a brief description of each type is given below.

Frame construction embraces all buildings with exterior walls of wooden framework sheathed with shingles, plywood, or lumber siding; veneered with brick, stone, or tile; or covered with stucco.

A wood frame is composed of a sill laid level upon the top of the foundation wall and either bedded in mortar or bolted to the foundation. The corner posts and studs are vertical members fastened to the sill and supporting at their upper ends the horizontal plate which carries the ends of the roof rafters. The first story floor joists rest upon the sill, and the second story joists upon ribbons which are horizontal pieces supported by the studs or fastened to them at the floor level. The studs are most often 2"x4" spaced 16" on centers but they may be 2"x6" for it is usually necessary in every house to use 6" studs in some of the walls to conceal plumbing. To the studs is nailed sheathing which may be tongue and grooved lumber, plywood, or a rigid type insulating board. The lumber sheathing should be lain at an angle of 45 degrees to the vertical line of the studding as diagonally sheathed walls are much stronger than those that are horizontally sheathed. Lately, it has been demonstrated that Douglas fir plywood is superior to all other types of sheathing in relation to rigidity. ¹⁄₄" plywood makes a wall 5.9 times as rigid as 25/32" horizontal sheathing and 40% more rigid than diagonal sheathing.
The rigid insulating board may be used as sheathing where insulation is stressed but these boards do not add a great deal of strength to the building consequently, these boards are used mostly in the interior of the house.

The value of the building paper that is placed between the sheathing and exterior wall cannot be over estimated for tests made at the University of Wisconsin show a reduction in air leakage from 12.3 ft. per hour per sq. ft. of surface to 0.3 ft. when good quality building paper was stretched over the sheathing in vertical strips.

The final exterior covering may consist of wood or artificial shingles, one of many styles of lumber siding or water-proofed plywood nailed onto the sheathing and studs. Or a brick, stone or tile veneer may be used. A wood frame house with a masonry veneer in reality looks exactly like a solid masonry house. For a brick, stone, or tile veneer the framework of studding, sheathing, and building paper are erected the same as the building with a wood exterior only one layer of masonry is substituted for the exterior wood siding.

For a stucco exterior a heavy roofing felt is substituted for the building paper. Upon this felt, ¹⁄₄" furring strips are then nailed. To these furring strips a wire mesh, metal, or wood lath is nailed. To this lath is applied the stucco which is a cement plaster, consisting of cement and sand, or cement, sand and lime, mixed in varying proportions. Stucco may also be applied to a masonry backing such as tile or concrete.
In the solid masonry house the walls for most residences are 8" thick in the case of brick, hollow tile and concrete. Stone is more often 12" in thickness.

To have better insulation the interior finish such as plaster should not be applied directly to the wall. By using furring strips to separate the wall and the plaster an air space is created that does much to prevent the passage of heat.

In recent years a house was either of wood or masonry construction but a newcomer has entered this field. In the Eastern sections of the United States metal is being used as a home building material. These all metal houses are constructed in two different manners, the more costly and best appearing type has skyscraper type steel framing covered with zinc. The zinc has an advantage in being rust resisting and retains a natural blue gray color indefinitely. The material is manufactured in two foot wide plates, from several feet in length to three stories high, which eliminates horizontal joints. The floors and ceiling are 4½" steel and concrete.

In the cheaper all metal houses the steel framework, corresponding to frame construction is either bolted or welded together. The siding consists of steel sheets, in some cases stainless steel, riveted or welded together.

At this time steel construction is in the experimental stage and is not discussed to any great extent in this thesis.

INSULATION:

Insulation is slowly becoming recognized as a very important part of a house because in winter, insulation acts to keep heat inside buildings, and in the summer to keep it outside.
Not only does insulation increase the comfort in homes but also cuts down heating costs by decreasing the annual fuel consumption which in turn allows the use of a smaller heating unit. In the Northern states where winters are cold and windy, insulation definitely pays for itself as illustrated below.

The American Society of Heating and Ventilating Engineers carried out a survey to determine the cost of heating houses that were poorly insulated or were built of materials that were poor insulators. Their method of discovering this cost is as follows.

For Chicago, Ill. it was found that the average temperature between October 1 and May 1 was 36.4 degrees F. The average dwelling in Chicago is maintained at 60 degrees F. during seven sleeping hours and 70 degrees during the remaining hours of the day. With the thermal conductivity of a wall which is the amount of heat (measured in British Thermal Units) lost through a wall per. sq. ft., per hour, per degree difference in temperature between the inner and outer sides of the wall, the engineers were then able to determine the heat lost for the entire winter. An average house with 2,000 sq. ft. of wall space was used for the calculations.

The total amount of hour degrees temperature difference for an average winter period extending from Oct. 1 to May 1 for Chicago, Ill. was determined as follows.

1. The average temperature between Oct. 1 to May 1 in Chicago, Ill. is 36.4 degrees F.
2. The average temperature difference for the "Waking Hours" is (70-36.4 degrees) 33.6 degrees F.

3. The total hour degrees temperature difference for the "Waking Hours" is 3,604 (number of waking hours between Oct.1 and May1) times 33.6 which equals 121,094.

4. The average temperature difference for the "Sleeping Hours" is (60-36.4 degrees) 23.6 degrees F.

5. The total hour degrees temperature difference for the "Sleeping hours" is 1,484 (number of sleeping hours between Oct.1 and May1) times 23.6 which equals 35,022.

6. The total hour degrees temperature difference between Oct.1 and May1 is 121,094 (Waking hours) plus 35,022 (Sleeping hours) which equals 156,116.

The thermal conductivity of a wood frame house with siding, building paper, sheathing, studs, wood lath, and plaster is .227. Therefore, .227 times 2,000 (sq. ft. of wall area) times 156,116 equals 70,876,664 which is the number of B.T.U.'s lost through the walls of the house during the winter heating season. It was estimated that the average heating system would give 50% efficiency therefore, a pound of coal would give off 6,000 B.T.U.'s. 70,876,664 divided by 6,000 equals 11,812 pounds of coal needed to make up for the heat losses through the walls of the house.

The identical frame wall except for wood sheathing nailed to the studs on the interior side of the wall with the lath and plaster upon this sheathing, has a thermal conductivity of .122. This increase in insulation given by the extra sheathing decreases the heat losses from 11,812# to 6,349# of coal
and the comfort within the house is increased immeasurably.

Below is the thermal conductivity of the important building materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal conductivity per inch of Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>1.00</td>
</tr>
<tr>
<td>Hollow building tile</td>
<td>3.43</td>
</tr>
<tr>
<td>Concrete building blocks</td>
<td>4.84</td>
</tr>
<tr>
<td>Brick</td>
<td>5.00</td>
</tr>
<tr>
<td>Stucco on wire mesh</td>
<td>8.00</td>
</tr>
<tr>
<td>Concrete</td>
<td>8.30</td>
</tr>
<tr>
<td>Steel - not given but higher than any of the above materials.</td>
<td></td>
</tr>
</tbody>
</table>

It can be seen that wood is a much better insulator than the other building materials. However, in the actual wall of a house there is not such a large difference in the insulating values because the masonry walls are thicker than frame walls. The thermal conductivity of various wall types are as follows.

1. Frame construction - Bevel siding, building paper, sheathing, studs, sheathing, wood lath and plaster. 1.122
2. Masonry - 8" brick, furring strips, wood lath and plaster. 1.209
3. Frame - Brick veneer, building paper, sheathing, studs, sheathing, wood lath and plaster. 1.216
4. Frame - Bevel siding, building paper, sheathing, studs, and wood lath and plaster. 1.227
5. Frame - Stucco on wood lath, felt, sheathing, studs, sheathing, wood lath and plaster. 1.234
6. Masonry - 8" concrete, stucco exterior, furring strips, wood lath and plaster on the interior. 1.246
7. Frame - Stucco, metal lath, sheathing, studs, metal lath and plaster. 1.255
8. Masonry - 8" hollow tile with plaster on masonry in the interior.

9. Masonry - Brick exterior, 4" hollow tile backing and plaster on masonry in the interior.

10. 8" brick with plaster on brick in the interior.

11. Masonry - 8" concrete block, stucco exterior, plaster on masonry in the interior.

12. 8" concrete, stucco exterior, plaster on masonry in the interior.

There are now a great number of manufactured insulating materials on the market that are much better insulators than any of the principal building materials such as wood, brick, stone, etc. These insulating materials are relatively inexpensive and easy to install as the house is being constructed. In a cold climate some type of insulation is undeniably a good investment.

This manufactured insulation falls into the following classifications.

Rigid insulation - manufactured chiefly from plant and wood fiber. It is produced in panels of various sizes and may be used solely for insulating values, although because of its rigidity it is generally used as a combination insulating and structural material, such as outside sheathing, plaster base, or inferior finish for walls and ceiling.

Semi-rigid - less rigid than above, made from grasses.

Flexible insulation - loosely felted as wood fiber, hair, grass, Kapok or mineral substance, usually covered on both sides by paper or fabric. It can be inserted between wall studs.

Fill insulation - granulated, shredded or powdered material
such as granulated cork, shredded vegetable fiber and fibrous or powdered material such as gypsum, limestone or other rock from slag and metal refineries. It is used to fill in spaces such as between studding.

DEPRECIATION, INSURANCE AND MAINTENANCE:

The annual depreciation, insurance and maintenance costs are not to be taken lightly when considering the selection of a building material. These costs are not large any one year but when taken over a twenty or thirty year period their total becomes amazingly large. In fact, these costs may in a comparatively short time equal the original cost of the building. Consequently, a building material that may be insured at low rates, depreciates slowly, and requires very little maintenance is to be desired in a house.

MAINTENANCE:

In both masonry and frame houses the secret to low maintenance is a good foundation and the use of good materials.

In masonry houses the maintenance cost should be very low but in the case of inferior construction which usually means that low grade mortar has been used in bonding the brick, stone, or tile. Cracking, which greatly mars the appearance, is difficult to repair, and weakens the structure, is likely to result.

In a frame structure, there is no danger from cracking but there is danger that the house may lack in strength and rigidity due to the use of the wrong materials and insufficient bracing. Since it is nearly impossible to correct these flaws
in construction after the house has been completed the selection of a honest competent contractor is a wise investment. However, assuming good construction such as a sturdy, durable, foundation, decay and termite protection, and a strong well braced building, the only maintenance cost of any importance should be painting. Wood, metal and some cases stucco and brick should be painted to prevent disintegration due to various elements. Some metal houses such as those constructed of zinc do not require paint but in most metal houses paint is very important because rust would soon destroy the building. Although, wood does not disintegrate as does steel when exposed to weathering elements, it should be kept painted because its appearance is improved and decay is prevented.

Paint fails through the loss of elasticity and toughness and the increase in brittleness due to gradual oxidation. Either chalking or cracking results, depending upon the composition of the paint. Paint of the proper composition will chalk mildly without washing off and will often maintain a good protective film free from cracking and scaling for a period of from three to ten years. Climatic conditions are largely responsible for this wide spread of time. For the wet climate of the Pacific Northwest, the average coat of paint should be renewed every four or five years in order to best preserve the wood or metal, maintain a good appearance, and to keep the cost of each painting at a minimum.

In summing up the relative merits of masonry, wood, and metal in relation to maintenance costs, the masonry houses
have the lower maintenance cost for they do not require painting. This statement is based upon the assumption that each of these types are well constructed and protected and therefore, do not require many repairs. However, many people believe this cost is offset by the fact that painting varies the house and makes it look new every few years.

DEPRECIATION:

The depreciation of a house is the result of two factors. First, the decreasing in value of the materials that make up the house due to decay, weathering, or other damage. Second, the result of the house going out of style. Which of these two factors is the most important is difficult to determine. Generally people accept the idea that stone and brick depreciate much less than do frame buildings. This is probably due to the fact that in general frame buildings have been poorly constructed more often than masonry buildings because a person with limited experience can erect a frame building whereas, the masonry house requires more skill to erect and therefore only the more highly skilled men have attempted to build these houses. Also, another factor that makes wood look as if it depreciates faster than masonry is the fact that frame buildings as a whole are not kept painted.

When the masonry and wood houses have been well constructed and maintained they will last for centuries as illustrated by many of the early Colonial and European houses that are at present in perfect condition. Consequently, the constantly changing styles in architecture are in most instances
largely responsible for the depreciation of houses for the owners of houses that are out of style lose interest in them due to their appearance and lowered value and do not correctly maintain the house which soon becomes in such a condition that no one will live in it. Therefore, the home builder should make a careful study of the various styles of architecture and select one that has been popular in the past, is popular at present and is very likely to be popular in the future.

INSURANCE:

The annual cost of fire insurance is on the average about \( \frac{1}{5} \) of 1\% of the cost of the house.

Average fire insurance rates are as follows:

<table>
<thead>
<tr>
<th>Type of Build.</th>
<th>Type of roof.</th>
<th>Rate per $100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood frame with wood siding or masonry veneer</td>
<td>Wood shingle</td>
<td>$0.35 $0.70</td>
</tr>
<tr>
<td>&quot;</td>
<td>Fireproof</td>
<td>$0.30 $0.60</td>
</tr>
<tr>
<td>Masonry &quot;</td>
<td>Wood shingle</td>
<td>$0.30 $0.60</td>
</tr>
<tr>
<td>&quot;</td>
<td>Fireproof</td>
<td>$0.25 $0.50</td>
</tr>
</tbody>
</table>

As the table indicates the solid walled masonry house can be insured at slightly lower rates than the wood frame house but this slight advantage does not offset the higher initial cost of the masonry house.

EASE OF ALTERATION:

Only a glance at the houses built 20 to 30 years ago is needed for one to come to the conclusion that ease and cheapness of alteration are important factors in a building material; for styles in houses are constantly changing. In this factor wood proves itself far superior to all other building materials for the ease with which wood sided walls can be altered or added to is well known. Spaces in frame walls
are readily accessible for changes in electric light wiring, plumbing and heating systems, telephone and radio wiring and other accessories in the modern home. Whereas, in the masonry houses there is often no spaces in the walls for these various accessories. Not only are wood walls easy to alter but they can be altered much cheaper than masonry walls. A wooden wall with the exception of shingles may be torn out and the same material used again, while a masonry wall requires more time to be torn down and the material is usually ruined so far as further use is concerned.

STRENGTH AGAINST WIND AND EARTHQUAKE:

The Los Angeles, California earthquake in 1933 definitely demonstrated the superiority of wood over masonry construction in earthquake areas. It was found that wood and steel construction withstood the quake very well due to their elasticity. Whereas, the rigid non-elastic materials such as brick, tile, and stucco were highly vulnerable to the quake. Consequently, the trend in earthquake areas is to build of wood and steel rather than masonry.

In reference to resistance to wind the general tendency is for more wood houses to be destroyed than other types of houses due largely to poor construction. In masonry houses the walls and foundations are cemented together and are of heavier material than wood and consequently can withstand a stronger wind than wood.

Many frame houses are poorly constructed to the extent that they are not anchored in any way to their foundations.
Therefore, a homebuilder in a windy country should make sure that his house is securely anchored to its foundation.

In both frame and masonry construction the roofs are often blown off which is also due to their not being well secured to the building.

If frame and masonry buildings are well constructed they should not be effected by anything but the most violent wind storms.

FIRE RESISTANCE:

Undoubtedly, lack of fire resistance is one of the greatest defects that wood has as a building material. However, this lack of fire resistance would not be of such importance if correct construction methods were used and human carelessness eliminated. Over one-fourth of the fires are caused by matches and cigarettes. The remainder are due largely to faulty construction, defective electric wiring, and sparks on the roof.

One of the important causes of fires that could be easily corrected are those fires due to overheated chimneys and flues. Great care should be taken by the owner of a building to make sure that nowhere does any of the woodwork of the house bind the chimney. The careless or incompetent carpenter is always tempted to use the chimney to steady and perhaps brace his work, and such construction is dangerous. The chimney is almost certain to settle, and as it does so it binds against the woodwork and hangs there, a crack results, and sooner or later sparks reach the dry timber and fire results.
Equally important, but, neglected even more in frame construction are fire stops. The hollow spaces between the studs offer an easy passage for the spread of fire, especially for fires that begin in the basement. A fire stop consists of a filling of brick and mortar or cement at each floor between the studding. This cheap and simple precaution does much to confine the fire and thereby slows up its progress.

In recent years, great progress has been made in the fireproofing of wood and it is only natural to expect that in the near future, that a process will be uncovered that will make wood absolutely noninflammable.

The processes developed at the present time serve to prevent the starting and to retard the progress of the fire. This fire retardant wood when subjected to prolonged flame will eventually ignite the same as other wood, but taking into consideration the fact that most fires are the result of a small flame such as is produced by a match, cigarette, spark, etc., it can be seen that this fire retardant wood prevents many fires. In those cases where the fire gets started; it slows up the progress of the fire enough to allow the homeowner a much better chance of saving the house.

There have been several fire retardant processes developed, all of which work upon the principal of keeping oxygen out of the wood by filling the cells with chemicals.

One of the most successful processes thus far developed is: The withdrawing of the sap, resin and gum by vacuum, introduction of an ammonia solution under pressure and kiln
dry the wood. Crystals of the absorbed solution remain in the wood and these fusing at high temperatures, retard combustion. Ignition of hard wood, which would otherwise ensue in a few seconds, has been shown by tests to be delayed five minutes by this treatment.

The houses of to-day are not nearly so fireproof as they ought to be. On the other hand, this is not a first requirement of building materials at present except in the thickly populated large cities. Few houses are so large as to constitute much risk to life when they burn. Insurance rates are not so much lower for fireproof houses as to offset the additional cost. For the immediate future non-combustibility must be reckoned as a credit rather than combustibility as a debit, inasmuch as the house will probably always contain sufficient other combustible materials in the form of furnishings to establish a good fire.

COST:

As was pointed out in the introduction, cost in low and medium income groups is the most important factor that the home builder must consider when he selects a building material.

Cost is difficult to determine accurately because the great variety of conditions that effect the cost of a house never remain constant. Therefore, it is common to find the cost of identical houses varying as much as 30% in different sections of the United States.

Rough estimates show that 8" solid walled brick house
costs about 12% more than would a frame house. Hollow tile with stucco exterior and concrete block cost 10% more than would a frame house.

The following table is a fairly accurate indicator of house costs. These costs are calculated by the cubic foot. The average sized house contains 2,000 sq. ft.

Type of construction. | Cost per cu. ft.
--- | ---
Ordinary frame - 4,5 to 6 rooms, bath, hot-air heat. | $.27 - .32
Frame - good construction, bath, laundry, hot-air heat and Yellow pine floors. | .32 - .37
Special - frame dwellings, all conveniences, hot-water heat, hardwood floor. | .40 - .50
Class C type - small brick veneer, 5 to 6 rooms, bath, hot-air heat, hardwood on first floor. | .33 - .38
Class B type - brick veneer, 6 to 8 rooms, bath, all conveniences, hot-water heat, hdw. first floor. | .42 - .47
Class A type - brick, tile backing, all conveniences hardwood finish. | .55 - 65

Even though these tables cannot be accurate for any one locality they do indicate the average spread in costs between masonry and wood. In Eastern United States this spread would probably narrow down because of a small supply of timber while in the West this spread would be greater. However, wood construction makes a substantial saving over masonry in any part of the United States.
The interior of houses have many substitutes for wood but in most instances wood still maintains its superiority; for it is in the interior of houses that people demand beauty and wood is still supreme in this field for the wood substitutes, although attempts are made to imitate wood, cannot capture the warmth, charm, and beauty of wood. Therefore, it is upon other factors that substitutes must prove their advantages over wood.

The floor is one of the costlier and most used parts of a home and it is here that substitutes are making a strong bid to supplant wood.

Steel and wood are the two types of materials used in constructing the framework with which to support the floor, with wood being the most commonly used. In recent years a steel framework with a concrete slab for the flooring has been increasingly used in fireproof construction. In a few instances a steel framework has been used to support wooden floors but it is questionable if steel has any distinct advantages over wood when used in this situation. In case of fire these steel joists often prove to be more dangerous than wood. For the steel beams will expand, damage the walls and soon collapse without warning from loss of strength due to the rise in temperature. Wood beams or joists are less affected by the intensity of the fire than by its duration because their strength diminishes only in proportion to the loss of cross section with the charred surface acting as an insulator. In case of collapse they give ample warning and their removal is
much less costly. Therefore, it can be seen that unless the house is fireproof or long spans are required, wood is equally as good as steel in small light houses.

The floor joists upon which the flooring rests are usually 2" or 3" thick from 6" to 14" deep and are set on edge 12" to 16" apart on centers. Upon these floor joists the sub-floor is laid diagonally in order to increase the strength of the building. This sub-floor may be a low grade material but should be well nailed as this adds strength and prevents the floor from squeaking. Recently 5/8" Douglas fir plywood has come into use as sub-flooring. It has the advantage over lumber in that it can be lain much faster, increases the strength of the building, is a better insulator, and is less likely to squeak.

Upon the sub-flooring a layer of heavy building paper should be lain to further insulate the floor.

Southern Yellow pine, Douglas fir, Oak, and Maple are the woods most generally used for the final flooring. Quarter-sawed White oak is preferred for its hardness and beautiful grain. Maple is also a favorite flooring material and is even harder than the White oak but its grain is not so interesting. Vertical grain Douglas fir and Southern Yellow pine are usually partially covered with linoleum or rugs as they are not as beautiful nor as hard as oak or maple. In the bathroom concrete or tile floors are recommended due to the floors being damp or wet much of the time.

The steel and concrete slab floors are constructed with steel I beams supporting the slab. The concrete slab is
is usually reinforced with woven wire mesh or expanded metal in wide sheets which acts as both reinforcement and as a form to hold the concrete. If correctly finished the concrete floor has a smooth surface that may be of a variety of colors, many of very beautiful. Tile, rubber, cork, or linoleum may also be used on top of this concrete slab as the final flooring.

The concrete floor has only one distinct advantage over wood floors which is resistance against fire. Even this advantage is partially nullified by a fireproofed lumber produced by the Protexal Corporation, Kenilworth, N.J. This lumber is impregnated with incombustible salts. Red oak and maple used for flooring and trim were tested and approved by the Underwriters Laboratory of Chicago, Ill. as being "practically noncombustible and non-inflammable." Workability was found to be unimpaired; and its appearance and ability to take paint and varnish unchanged.

The wood floor is cheaper, easier to construct or alter, warmer, easier on the feet, and in most instances has a more pleasing appearance. The concrete floor is probably easier to keep clean and if constructed correctly may wear less than wood. However, either material should last the life of the house except in places of extremely heavy wear.

Equally important as the floors are the interior walls of the house. At the present time plaster is the most popular interior finish with wall paper running second and in the more beautiful and expensive homes wood paneling. However, plywood and numerous insulating boards are becoming popular interior finishes.
Plaster is applied upon either wood or metal lath. Wood lath are about 1/4" thick, 1 1/2" wide and either 32" or 48" long and nailed to the studs with 3/8" intervals between them. The metal lath may be woven from wire into a fabric with 2" or 2 1/2" square mesh called wire lath or it may be formed by cutting slits in metal sheets called expanded metal lath.

There are three coats of plaster applied to the lath - the scratch coat, brown coat, and finish coat. The scratch coat consists of stiff lime putty one part by vol., sand three parts by vol., and hair or fiber 6 pounds per yard of plaster. The brown coat consists of stiff lime putty one part by vol., sand four parts by vol., and hair or fiber three lbs. per yard of plaster. The finish coat consists of lime putty without sand to which is added plaster of paris.

Till recent years wood lath was the only material used as a base for plaster but metal lath is becoming increasingly popular. This popularity is due to the fact that it is fire-proof, can be applied much faster, does not shrink, warp, nor stain the plaster. However, the wood lath has the advantage of being almost twice as cheap as the metal lath. In addition it has been shown in recent tests made by the Forest Products Laboratories that plaster on wood lath increases the stiffness of horizontally sheathed wood walls over 200%; whereas, metal lath does not increase the stiffness of wood framed buildings and requires more plaster to embed the lath. Also, the wood lath is a much better insulator than the metal lath for the thermal conductivity of wood lath and plaster equals 1.75 and metal lath and plaster equals 2.32.
The base for wall paper may be common lumber sheathing, plywood, or a rigid type insulating board. The insulating board is being used in larger and larger amounts as a base for wall paper because it not only insulates as its name indicates but it can be put up rapidly and cheaply and has a smooth surface. As to price, in most instances it is slightly higher than either lumber or plywood sheathing.

Plywood is being increasingly used for the interior walls and ceilings of homes. Its advantages being that it can be erected in a short length of time and eliminates the use of a large amount of water such as is used in plastering, for it is estimated that 1,000 gallons of water is used in plastering a six room house. This water must be absorbed by the siding, floors, and window trim, which often leads to twisting and warping. However, the beauty and insulating qualities of plywood are probably its outstanding advantages over plastered walls. A 5/16" plywood panel has a thermal conductivity of 1.31 whereas, the plaster with metal lath is 2.32.

Appearance is predominately in favor of plywood for many different color combinations may be used upon the walls; or they may be varnished and left natural. Plaster due to its solid color tends to become monotonous. Also, plywood is never in danger of cracking or falling from the walls and ceiling as is often the case with plaster.

Insulating boards are being used as an interior finish in many homes at present. Many of the insulating boards are
manufactured with a smooth pleasing finish and with grooves in them to represent squares or planking which breaks up the monotony that a solid flat wall would ordinarily give. These boards have one definite advantage over plaster and plywood in that they are better in deadening sound.

At the present time wood has very little competition in the ordinary home in relation to interior finish such as door trim, baseboards, and moldings. In office buildings metal is replacing wood because it is fireproof. But in the home the warmth and beauty of wood offsets this inflammability factor. In fact, competing materials concede wood's advantage in this respect by striving to imitate its natural beauty.
There is a proverb that says, "A house amounts to a foundation and a roof." This saying probably isn't always true but it does bring out the point that the roof is an important part of any house. The roof is one of the most conspicuous parts of a house and it also bears the responsibility of keeping the snow, wind, and rain out of the house. Consequently, the type of material that goes into the roof should have both beauty and the ability to withstand weathering.

The framework that supports the roof covering may be either steel or wood. In domestic housing steel has not as yet played a large part as a roof framing material due to the fact that steel has no outstanding advantages over wood except for the fact that it is fireproof. The natural question is to ask "Isn't steel more rigid and durable than wood?" This is true but in this case the wood framing does not come in contact with any weathering elements and therefore is not subject to any type of decay and will last for centuries. Rigidity is an important element in a roof framework but in the average house the roof spans are short and therefore wood is sufficiently strong to serve the purpose. Therefore, since steel is more expensive and difficult to erect than wood, it is used only in those houses where complete fire resistance is demanded.

The wooden rafters which make up the framework of the roof and support the entire roof load, for an average span, have dimensions of 2"x4" and are spaced at 16" or 24" center to center. In the case of heavy roofing materials such as tile or longer spans the dimensions are increased proportionately.
The pitch or slope of the rafters should not be less than 5" rise to the horizontal foot for wood, asbestos, tile, and slate roofing. The reason being that the wind and rain will blow up under the shingles if the pitch is too flat. Where flatter roofs are desired, sheet metal or built up roofing should be used.

The sheathing may be either wood, insulating board, or a masonry slab. The wood sheathing may be laid either as a solid covering over the rafters or laid in strips cross-wise on the rafters about 4 or 5 inches apart. These strips are usually 1"x4" and are called shingle lath. It can be seen that this method allows greater heat losses than the solid sheathing but in some climates where the shingles are likely to become saturated with moisture the solid sheathing does not allow for good ventilation and thereby brings about decay. The solid sheathing may be either shiplap lumber or plywood, with plywood rapidly becoming the favorite as it is a better insulator and can be lain much faster. The insulating boards have the same advantages but is not as strong as the plywood.

In the fireproof construction the sheathing may be a masonry slab of some type usually gypsum or concrete with steel reinforcement. These slabs may have wood nailing strips embeded in them, porous terra cotta, or nailing concrete used to receive the nails.

It is apparent that for the average house the wood sheathing is the logical material to use for it is a better insulator, cheaper, lighter, easier to construct and alter, and so far as fire resistance is concerned the sheathing is
between the interior ceiling of the house and the exterior roof covering consequently, fire would not be a big factor.

Upon the wood sheathing there should be a good grade of building paper in order to better insulate the house. For the final exterior covering there are various types of roofing materials each varying widely in appearance, weight, cost, durability, and fire resistance. The most common types of roofing are wood, asphalt, asbestos, slate, tile, and various metal coverings the most important being copper.

Wooden shingles are manufactured largely of Western Red cedar, Redwood, and Cypress with Western Red cedar being used the most. The common sizes in shingles are 16 and 18 inches long, random widths, about a quarter inch thickness at the butt and half as much at the slim end. With 16 inch shingles about 4 1/8 inches are usually exposed to the weather.

In any type of roof covering the manner in which it is laid and the type of materials used to fasten it to the sheathing is equally as important as the materials used. For a good material incorrectly used is no better than an inferior roofing material used correctly. For wooden shingles the important items to keep in mind are that edge grained rather than flat grained shingles should be used as they are not as susceptible to decay and are not as likely to warp and cup as the flat grained shingles. Also that each shingle should have a fastening of at least two nails and these should be zinc coated or copper nails since uncoated wire
nails rust through and release the shingles.

A correctly shingled roof should last at least twenty years with little or no repairs, in fact, many shingle roofs last double this length of time.

In recent years asphalt shingles and asphalt roll roofing have been used as roofing materials to a great extent; due largely to intensive advertising campaigns by the manufacturers of these materials. Asphalt shingles are made up of a asphalt base with a peboly mineral surface. This mineral coating may be in a variety of colors thereby giving the homebuilder an assortment of colors to choose from. Although, the appearance of the wood shingle is better in most types of architecture such as Colonial and English style houses.

There are many different grades and brands of asphalt shingles some of them being inferior to others but the better brands are guaranteed to last between fifteen and twenty years and sometimes longer. Asphalt shingles owe much of their popularity to the fact that they are fireproof. However, this is only partially true because in some instances the mineral coating washes or blows away and the asphalt that is exposed will catch afire.

The asphalt roll roofing is a cheap inferior roofing material that should be used only on temporary buildings. Its main defect lies in the fact that it soon tears away from the nails holding it and then the wind whips it off the building. Its advantage lies in the fact that it is less
expensive than either wood or asphalt shingles.

Asbestos shingles are made to imitate wood shingles in shape, size, and to a certain extent appearance. They are very durable, do not warp, shrink, or swell, and are fireproof. They are composed of about 15% asbestos fiber and 85% cement formed under great pressure. These shingles with their ability to resist fire and extreme durability would seem to be the answer to the homebuilders prayer. But they have a big disadvantage in that they are more expensive than asphalt or wood shingles. They are also heavy, easily broken, and in industrialized areas give off a dingy appearance due to collecting dirt and dust worse than other shingles. Since appearance is prized highly in shingles the manufactures of asbestos shingles have tried to capture the charm in color and texture of wood shingles; but they have not as yet succeeded for, the shingles never change their tone, never ripen or mellow with age.

Slate roofing is made from slate rock which can be split into thin sheets. The common commercial sizes of the sheets are 13"x16" and 14"x20" on the surface and 3/16" and 1/2" thick. Slate like other shingles is lain upon wood or masonry sheathing. The slate shingles are fastened to the sheathing in the same manner as other shingles as nail holes are drilled in the slate at the factory. The nails should be high grade durable nails that do not rust, for a slate roof lasts the lifetime of a house.

Slate comes in a variety of colors, many of which blend beautifully with some types of architecture. Slate in addition to being durable is also fireproof. Slate
makes a rather heavy roofing and this is its only outstanding defect for this weight increases the freight rates and makes it too expensive for the average house. Therefore, in most instances it is used only in houses near the slate quarries which are located principally in the New England States.

Tile is the heaviest and one of the most expensive of the roofing materials. Roofing tile is made of clay and burned much the same as terra cotta. Like slate it is very durable, fireproof, and does not warp or twist. However, provisions must be made for expansion and contraction due to heat and cold. Although tile makes a beautiful roof, it is not used to a great extent except in the Southern part of the United States on houses of Spanish type architecture.

The wooden shingle is overwhelmingly superior to the other roofing materials as to insulating value. The insulating value of the various roofing material per commercial thickness is as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>B.T.U.'s lost through com. thickness of shingle per hour, per degree difference between the inner and outer sides of the roof.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos</td>
<td>6.00</td>
</tr>
<tr>
<td>Asphalt</td>
<td>6.50</td>
</tr>
<tr>
<td>Slate</td>
<td>20.74</td>
</tr>
<tr>
<td>Wood</td>
<td>1.60</td>
</tr>
</tbody>
</table>

No discussion of roofing materials is complete without mentioning the initial cost. Although this cost is not too accurate due to a great variety of conditions affecting the costs.
Data published by the Home Owner Loan Corporation list the average price of the better grades of roofing materials per square as follows:

<table>
<thead>
<tr>
<th>Material</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt shingles</td>
<td>$13.70</td>
</tr>
<tr>
<td>Wooden</td>
<td>$14.00</td>
</tr>
<tr>
<td>Asbestos</td>
<td>$23.95</td>
</tr>
<tr>
<td>Slate</td>
<td>$21.00</td>
</tr>
</tbody>
</table>

Tile - not listed but is usually the most expensive of the roofing materials.

Over a long period of time the permanent type materials such as slate are probably the cheapest but for the low income family who cannot afford a large initial investment the cheaper materials are probably the best selection.

In summing up the advantages and disadvantages of wooden shingles as compared with the other roofing materials, the chief objection to a wood roof is that it will burn. This has resulted in ordinances prohibiting shingle roofs in 560 of the larger cities in the United States. However, in small towns and country homes there is not a great deal of danger from fires starting on roofs, for statistics show that only 8% of the fires in homes are caused by sparks on the roof and the majority of these were in the larger and more thickly populated cities.
CONCLUSION

As was indicated in the previous pages, all the building materials now used in house construction have desirable properties but, few if any, of these materials have as many desirable properties as wood. Its only important failing being its lack of fire resistance, in which a great deal of progress is being made to correct. Therefore, at the present time wood is the outstanding building material in residential construction.

What the future holds for wood is difficult to determine. The field of Chemistry is making rapid progress in developing new materials any one of which may revolutionize the building industry. For example, although at present it is too costly for low cost houses, glass has indications of becoming an excellent building material. Glass brick or large squares of glass are now being manufactured that allow the entrance of light, cannot be seen through, is strong and will not break under ordinary conditions, is a moderately good insulator, very durable and fire resistant. These glass brick are bound together by a synthetic resin.

Since there is a great amount of research now being made in lowering the cost of houses through decreasing labor costs, those materials that can be erected in large sections such as steel, plywood, concrete, and various building boards and plastics would seem to be the materials in which the future is the most promising.

Plywood has made the most progress in this field and
will undoubtedly become increasingly constructed in this manner.

Concrete and steel have both been successfully used in prefabricated houses but are both too expensive at the present time. Concrete has the biggest disadvantage in that the forms which are used in molding the slabs are difficult and expensive to change. Consequently, it is nearly impossible to have any variety in these prefabricated concrete houses unless there are a great number of forms constructed which means the cost will be so high that an ordinary concrete house would be equally as cheap.

There is a great deal of experimentation in plastics and many observers believe that these plastics will replace a great number of the building materials now in use.

Celotex Corporation recently brought out a new building board that may have possibilities. This board has a core of sugar cane fiber that is sandwiched between two outer layers of concrete and asbestos. However, like nearly all the new products being perfected the cost is prohibitive consequently, wood for the present must be considered the outstanding material in the residential field.
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