CHAPTER III

THEORY OF WOODEN CONSTRUCTION

In this chapter it is intended to examine not the whole of wooden construction theory, but only that portion which concerns the manner in which it was used in Gujarat. And the main reason why such an examination is required is that the use of wood is not at all obvious or logical at first glance. Even if it is assumed that wooden architecture was the norm for the whole of India once upon a time, that norm had long ago been discarded over major areas of the country and had survived only in areas still having substantial supplies of wood. According to this rule, Gujarat should have followed a non-wooden tradition for it certainly did not possess large quantities of timber, and whatever was available was not easily procurable, so that timber had to be imported all the way from Malabar. We saw in the previous chapter that one of the sources of the wooden tradition was the Indus Valley Civilization; but that only widens the area of enquiry. Why should timber 'lacing' have been used there at all? Besides, it still does not explain the use of the other two wooden techniques related to half-timbering. The answer to all these questions is still open.

The first point to be established is that woodwork in Gujarat was primarily an urban phenomenon. In the villages the vast majority of houses were of mud or stone rubble (I here exclude tribal housing from this description because that forms an exception). Stone rubble was extensively used in the Saurashtra
sub-division because the dryness of the climate makes the clay unsuitable for house-construction. Rubble stone could be freely picked up and by using selected clay mortar as a binding material, it could be used to make low, single-storey dwellings with a pitched roof. Wood was then required only for the latter. The fully mud house was the normal house over the whole of North Gujarat because the soil here is richer, and again, wood was used only for the roof. In both these sub-divisions the normal village house was a single-storey structure with an internal loft built into the rising portion of the pitched roof. No half-timbering or timber-bonding (or lacing) was used anywhere. The relative absence of the two-storeyed village house comes from the fact that there was plenty of land available and so there was no pressing reason to build upwards. Additional living space was made by either extending the loft, or by making a new house.

In the urban areas, on the other hand, two things were immediately noticeable. Firstly, almost all the houses were multi-storeyed. The normal house was double-storeyed, but with many going up to three and four storeys. It was obvious that this was because urban space was restricted and valuable, and additional space could only be had by building upwards. Secondly, the materials used in the urban house now showed a change. In Saurashtra the stone rubble continued to be used, but in better houses regular dressed stone (ashlar) began to appear, and in many examples the stone was accompanied by a network of bonding-timbers. In North Gujarat, the material used in the urban house was almost exclusively burnt-brick and in every case it was accompanied by some form of structural wood, i.e. either bonding-timber or half-timbering.

The above field observations made it clear that the appearance of wood was directly related to the presence of the multi-storeyed structure. And therefore, what had now to be examined was: why was wood needed in the multi-storeyed structure when stone/brick was readily available? Could not stone or brick alone carry the load of the structure? The other related
question is: Why did the urban house in North Gujarat abandon mud as the structural material and change over to burnt-brick? We shall examine each of these problems in turn.

(a) Change from Mud to Burnt-brick: It is not true that the multi-storeyed house cannot be made in mud. During field work we saw many multi-storeyed houses in mud and one is illustrated in Ill. 625a. The house is perfectly solid and structurally strong, and provides all the support required in this case. It seemed to us that the only defect of mud was that it must be getting washed away during heavy rains, and so we put this question specifically to the house-owners. We received the following surprising information.

There were two kinds of mud available in the village. One was the mud available in the fields; this is no use for house building because it gets washed away in rains. The second kind was the mud existing on the site of the village, i.e. the debris of the village itself and this had a special name in Gujarati: Gabhān (ગભાન). Technically speaking, it was the mud which had accumulated over the past centuries of occupation of the same site, and was 're-cycled mud'. This mud, we were told, was very resistant to rain and houses made of it lasted for generations. The house standing before us when this was being discussed was proof of this assertion. The lower reaches of the walls, which were fully exposed to the slanting rains during the monsoons, were undamaged and only here and there a few flakes had fallen off. This could easily be repaired every year afresh. Further discussion brought forth the information that Gabhan was rare, and as the village increased in population it became more and more difficult to procure. So much so, that when any old house collapsed and was to be renewed in brick, all the owners of mud houses would go begging for a few basketfuls of the old mud to keep for repairs to their existing houses.

We could not discover the reason why re-cycled mud is resistant to rain, but it seems that this kind of mud is devoid of those organic constituents and micro-organisms which make soil
fertile but at the same time soluble. Recycled mud resembles a hard, dry, non-plastic substance, and it is significant that it is never used for the making of pottery.

The other important observation regarding the mud house was that the strength of the compacted mud wall was more than adequate to bear the weight of wooden beams and roof-purlins, so that no structural wood embedded within walls was required for the purpose. That is the reason why the architecture in mud is simultaneously non-wooden. The mud wall needs neither bonding-timber nor half-timbering to assist it in its structural performance, and mud and wood are thus mutually exclusive. That is the simple reason why village architecture is largely non-wooden.

The one defect of the mud house which we could observe was that it looked untidy and required more maintenance. The mud wall can never be made absolutely straight because during working the wet mud tends to bulge out at certain places in an unexpected manner. In addition, the base of the wall has always to be much thicker than the top, so that a tapering wall has to be built, and this taper varies from wall to wall, giving to the whole a rather primitive appearance. The openings required for doors and windows are also not neatly cut out of the wall, but tend to be rather formless and inexact. In short, while the mud house meets all functional requirements, it does not provide prestige and status to a house-owner.

As already stated, since only Gabhan can be used, and the supply of such recycled mud must of necessity become less as villages grow beyond their original boundaries, the shortage of raw material must itself have forced many owners to turn to brick if they wanted a multi-storeyed house. This point needs some explanation. The single-storey house using non-Gabhan mud can survive if it provides a deep roof-overhang (i.e. a strongly projected roof) as a protection against rain. And there are many such village houses. But when the mud house becomes multi-storeyed,
the roof-overhang even if large does not protect the base of a
tall wall against slanting rain, and here damage will arise.
Therefore the Gabban becomes imperative in the case of the multi­
storeyed mud house, and the shortage of the raw material must
have caused problems. Added to this came the desire for status.
Both factors must have combined to produce a change over from mud
to brick. But it must be borne in mind that the essential
motivation for the change was the necessity for a multi-storeyed
house.

We have said that the restriction of space in an urban
area compelled the house to grow upwards, i.e. become multi-storeyed.
Why was the urban space restricted? The answer is because of the
needs of defence. The urban area was one which lived by trade, ,
commerce and manufacture, sometimes associated with administration.
The wealth which accumulated in an urban area was much greater
than in any village and it needed greater measures for its
protection. The political/administrative body which ruled over
territory also needed greater protection than the village. These
various compelling factors of economy and politics necessitated
in urban areas becoming fortified. City walls were thrown up
around urban habitations. The city wall set a rigid boundary to
urban growth, no house-owner wanted to live outside the city wall,
and when population grew it produced a pressure on urban space which
could only be met by vertical expansion. This was the genesis
of the multi-storeyed house, and it now becomes clear why it had
to be associated with urban development. Once vertical growth
became necessary, mud ceased to satisfy all the various requirements
of that growth, and brick had to be substituted.

(b) Association of Burnt-brick with Wood: The main question here
is: Why was brickwork alone found inadequate and had to be
associated with structural woodwork? We know that a brick wall
using lime mortar is completely stable and capable of supporting
all the loads coming upon it without any additional reinforcement.
Much of Mughal architecture in India used this technique (for
example in the Sarais), and a great part of the domestic architecture
of north India is of this kind. No structural woodwork appears in this case: It is an architecture in brick. It is specifically Gujarat which shows this association of wood and brick at a coeval period. And what our field observation has shown is that the brickwork in Gujarat did not, by and large, use lime mortar. It used instead mud mortar. The use of mud mortar in association with burnt brick is, of course, of very old standing and the practice was not restricted to Gujarat but was once common over large parts of India. Let us examine the references.

The reports of the Archaeological Survey of India (1862-1884) are here quoted as follows:

"Hindu architects of pre-Muhammadan period appear to have used mortar (meaning lime mortar) as little as possible, except on the roof, to keep out water effectively, and in the floor as a substratum, they used it nowhere else; in their walls my examination (Alexander Cunningham) has failed to discover anything like mortar of lime or surkhi; whether we take the walls of the Lalkot or citadel of Anangpal ... not a particle of mortar can be found; it is only used as a water-proof cement ... In the walls of the fort the core is built of rubble set in mud or reddish earth. In the temples, the same, wherever the walls are thick enough to have a core, but generally it appears that long headers were used of dressed stone, penetrating through beyond the core, from either side, and the interstices were filled with rubble carefully laid in earth." (1).

Regarding Bhitargaon, "It is built throughout of large well-burnt bricks ... laid in mud mortar." (2).

On Pataliputra, "The bricks were ... laid in clay mortar."(3)

Percy Brown describes Nalanda, "Between the joints a mixture of clay was interposed as an adherant, but only a very thin layer, as the bricks were brought into close contact. Lime mortar appears to have been known at this time although but only two instances of it have come to light ..."(4).
Rajendralala Mitra on Buddha Gaya, "The Great Temple and its appurtenances were built entirely of bricks ... The cement used in building is a finely-puddled, tenacious bluish clay, and only a thin layer of it was required, as the bricks, having well-dressed, smooth surfaces, sat on each other firmly ... Even in the construction of the arches nothing but clay has been used by way of cement ... On roofs and floors a compost of brick-dust and kankar lime was the mortar used, and a variety of it with a larger proportion of lime was used for plastering, ... This shows that the builders were not only perfectly familiar with the properties of lime mortar, but they used it extensively ... and yet, curiously enough, the builders never thought of lime-mortar in building radiating arches." (5).

Enough has been quoted to show that so far as north India was concerned mud mortar was the predominant binding material used in association with brick. Lime mortar was known but not used except for floors and roofs, and lime plaster was used on wall surfaces. Looking further afield, we have Taxila as reported by Sir John Marshall, "Up to that time (the time of the great earthquake) houses and structures of all kinds at Taxila had been built of rough rubble masonry in mud, with a facing of mud, or occasionally lime plaster ... (6). And the same author on Mohenjo-daro, "(Bricks) ... laid in mud or in mud and gypsum mortar combined. The latter material, however, is not found as an exclusive binding agent in any masonry ... Sometimes, but only very rarely, lime is used in combination with gypsum for lining the interior of water channels." (7).

M.S.Vats on Harappa, "Generally, mud alone was used as mortar, but sometimes gypsum appears to have been employed for pointing." (8).

Everywhere, in pre-Muslim India, going back to the earliest remains we find mud mortar reigning supreme. Lime mortar comes into general use as a mortar for wells (as opposed to floors and roofs) with the advent of the Muslims. Why was lime mortar not
used in the previous period when it so obviously gave a far greater strength to walls than mud mortar? This is a problem to which we have been able to find no definitive answer, but there are some strong indications.

The whole problem revolves around the size of bricks used. In the ancient period the size of brick was much larger than that used in later times. We quote again from the Archaeological Survey excavations at Multan by Cunningham, "It will be observed (from the debris brought up) that the bricks increase in size with the depth. This also is known to be the fact from existing buildings, as the bricks of all the Mughal buildings are very small and thin, not more than 5 or 6 inches in length and 1 inch thick; while those of the Pathan buildings are nearly double the size, and those of undoubted Buddhist buildings of an early date are still larger." (9).

The bricks used in Bhitargaon were 18x9x3 inches (10); at Hastinapur the flooring bricks were 11x11x4 inches (11); Vallabhipur bricks were 16x10x3 inches (12) while for Pataliputra Waddell writes, "On penetrating ... less than a foot brings us to the thin biscuit bricks of the Muhammadan period. On going further down we find the bricks become larger and larger during the earlier medieval period, till at the depth of twelve to fifteen feet we reach those usually found in the buildings of ASOKA'S age, measuring sixteen to eighteen inches in length by ten to twelve in breadth and two to three inches in depth."(12).

Now, when bricks of this great size are used, their structural behaviour is very similar to that of stone. Large bricks, well-finished and placed evenly over each other with a minimum of mortar, behave just like stone slabs and retain their stability because of their weight and the friction between surfaces. Stone construction in the ancient world was everywhere without mortar, the gravitational weight and ensuing surface-friction being sufficient to provide stability. Large bricks in ancient Indi
were used in exactly the same way, i.e. it was brick imitating stone construction. And hence only mud mortar was thought sufficient. Practical experience must also have shown this to be true. All that was needed was to make the wall sufficiently thick to prevent over-turning.

Turning now to the Muslim period, we have seen how the size of brick became drastically smaller, something like 6x3x1 inch, and resembling a 'biscuit'. This was precisely the kind of brick also used by the ancient Romans and it was used in association with lime mortar to produce 'concrete'. Ancient concrete was nothing else but lime mortar in which were embedded bricks of a small size (even brickbats were used) forming a kind of aggregate, in which the strength of the wall derived from the lime mortar. This was a revolutionary kind of construction quite different in principle from stone construction, and the aggregate or brick had to be small and fragmented in order to behave as an aggregate. The combination of lime mortar with brick thus arises in the Roman period, and it was taken over by the Muslims to make regular brick walls using lime not as a 'concrete' but as a mortar. The smallness of the bricks derives from this early tradition. One other possible reason for the small size of bricks could have been the scarcity of fuel for the burning process. India, being then rich in fuel, could afford to burn a larger brick, while the Muslim countries were always short of wood.

The Muslim architecture of India has been characterized by Percy Brown as follows, "The appearance of the arch in the building construction of Islam may be traced to the contact of the early Mohammedans with the architectural development of the post-Roman period ... But the ... arch ... was however only made possible by the introduction of another material hitherto little known to the indigenous masons. This was a cementing agent in the form of mortar ..." (13).
Coming now to the houses in Gujarat, we find a very strange situation, namely that the bricks used are small but the cementing agent is mud. In other words, we find here a conflict of structural traditions. Mud mortar was a very ancient tradition throughout north India and its prevalence in medieval Gujarat is therefore not surprising. The small brick, on the other hand, was employed in India by the Muslims and its presence in medieval Gujarat can tentatively be thought of as being derived from that source. We thus get two different traditions meeting here, one ancient Indian, the other medieval Islamic. The conflict led to a structural contradiction. Small bricks made sense only in the context of lime mortar; mud mortar made sense only in the context of large bricks. Small bricks used with mud mortar could never produce a stable wall. This must have been immediately apparent, and the solution to the dilemma was found in the use of structural wood. Timber, used either as a bonding-timber, or as half-timbering, was added to the brick wall in order to hold it together and give it the stability which mud mortar could not. (We shall see later how exactly wood performs this task).

The above theoretical explanation can be cross-checked in a number of ways. The most obvious is to see whether woodwork ever appears in association with lime mortar. Lime mortar appears predominantly in the Muslim buildings of India and it is perfectly apparent that structural timber, in our sense of the word, is absent in all such cases. Even within Gujarat itself the Surat caravanserais, for example, is brick-and-lime-mortar having no structural wood, while within a few yards away from it are a score of wooden buildings in brick-and-mud-mortar. The only exceptions to the rule are a few Gujarati buildings seen by us in which half-timbering appeared even though lime mortar had been used — these will be discussed at the appropriate place. They do not invalidate the general rule.

The second cross-check would be to see whether woodwork appears in association with large-sized bricks. All of the references quoted above, for Bhitargaon, Nalanda, Gaya, mention no structural wood. Thus, while the Buddhist reliefs no doubt show a wooden architecture, this is not what is found in the remains and it is
not established that woodwork was used in association with brickwork. The two might quite easily have been distinct techniques. The only ancient reference to wooden bonding-timber comes from the Indus Valley, and this may be considered at some length.

In general it can be stated that the Indus Valley remains show very little use of either half-timbering or wooden bonding-timbers. The numerous beam-holes at ceiling level show that beams were used but they rested directly on the walls and not on structural wood. Columns were rare (see page 77). The bricks found here were generally 11x5.5x2.5 inches, i.e. they were certainly not small but were mid-way between Buddhist and Muslim. The bricks at Lothal in Gujarat were large: 28x14x6 cm. Once again we find absence of wood associated with large-size bricks. Nevertheless we do have the few references to bonding-timber so that the technique was known, but there is a hitch. The full quotation reads, "This tower is raised on burnt-brick foundations reinforced by horizontal timbers ... The granary which is contemporary with the platforms and early towers is also laced with timber. The mistake of using timber in burnt-brick buildings appears to have been soon realized by the builders (it decays) and the practice was given up later." (14). (Italics mine). Now, this is most significant. The wooden practice was given up. In medieval Gujarat it was precisely this very practice which was retained.

It is important to note here that the use of wood in the Indus Valley was only sporadic, and that too in certain large and probably high structures, and even that was abandoned. The reason for such an abandonment is not clear. That wood decays could not have been the main reason for then they would not have used it in the first place. It is possible that the rate of decay was higher than what was expected, due to some unforeseen circumstances, such as repeated inundation with saline water, and that the practice was only then given up. What is of interest to us is that woodwork even in this area does not arise in
general in association with large bricks, so that our cross-check is positive.

The third check was to see whether in Gujarat itself there were any examples of brick and mud mortar but without woodwork. Our field survey showed that not a single multi-storeyed building of this type ever appeared. We did find single-storey structures of brick and mud where no wood was used, so that we could conclude that mud was not entirely weak even with small bricks, but its strength sufficed only for low heights. These were always the poorer houses in villages.

A final check was made through oral evidence. We continuously asked our informants throughout Gujarat (and they included carpenters) as to why wood was used at all when the brick wall was already there; and also why no lime mortar was used. The answers received were extremely varied and we give below their gist.

(1) The brick/mud-mortar wall has no strength and a hard kick is enough to topple it. It is the woodwork in the walls which imparts the strength.

(2) The brick/mud-mortar wall has a tendency to crack at places under the load of heavy ceilings and roof-purlins and this would lead to collapse if the timber did not hold it together.

(3) When unequal settlement occurs due to heavy rains, it is the woodwork which prevents the walls from collapsing.

(4) The whole house rests upon woodwork; if the walls are removed the house will still stand. This makes it strong.

(5) If an earthquake comes, the house will stand.

(6) Mud mortar is used because it keeps the house cool.

(7) Lime mortar is very expensive, it is cheaper to use mud mortar and strengthen it with woodwork.
Common to all these answers is that woodwork is both strong and relatively cheap. Even if all the answers are taken as so many after-thoughts or rationalizations of a given, but not understood, situation, still their wide distribution points to a common tradition which governed the use of woodwork.

When one sifts through all the evidence, what stands out as most inexplicable is the fact that even though small bricks were adopted in Gujarat, the accompanying use of lime mortar was not. It is not that they had no experience of lime, for it was extensively used in flooring, terraces, underground chambers, and plasters. But rarely as a cementing material for bricks. Here it will be useful to describe the making of lime mortar.

In general, lime (chunam) is procured from three sources: from limestone, sea-shells, and soil nodules called Kankar. Limestone is plentiful in the Saurashtra sub-division, but not so in North Gujarat. The alluvial plains of Gujarat are generally deficient in stone, so that limestone as a source of lime would not be economical for North and South Gujarat. Sea-shells are again not so plentiful as to provide a regular and common source of lime. All literary references mention the use of shell-lime only in the making of expensive plasters, particularly when these were to be painted over with wall-murals. There remains the last source: Kankar. Kankar arises in the soil as a natural product of the action of water on certain Calcic Feldspars and the resultant is a nodul of lime. This is obviously the cheapest source of lime, and much of the lime used in north India was of this kind. It is also found in Gujarat, but the question is whether it is found in adequate quantities. North Gujarat has a dry climate and it would be reasonable to assume that the formation of Kankar would not be as plentiful as, say, in the Gangetic plains. This could be one reason why lime was not used commonly even though small bricks had been adopted.
Once the lime was secured from any of the three sources, it still had to be heated to a temperature of some 900 degrees in order to change it into what is called Quicklime, and it was this Quicklime which was then kept immersed in water for a length of time to convert it into usable Slaked Lime. The Slaked Lime was then mixed with further water and sand to produce either mortar or plaster. But even after application the material had to be further kept wet to prevent quick drying. We thus see that the use of lime mortar was not a simple and inexpensive technical process which could be generally adopted. In arid areas with a scarcity of both fuel and water, it might well prove cheaper to use woodwork combined with brick/mud-mortar. Lime mortar would then be employed only in those structural parts where wood could not be used: for example in terraces, ceilings (subject to wetness), foundations, etc. The use of lime mortar specifically in those parts exposed to moisture is a clear indication of the attitude to this material. It was employed, not for its cementing qualities, but for its water-resistant qualities. (15).

As a corollary to the above, we may ask the question: Why was lime mortar so commonly used in the Muslim architecture of north India if it was so expensive? The answer would appear to be that there was no alternative. The alternative to lime mortar was mud mortar combined with woodwork, but north India had already become thoroughly deficient in wood and so this could not serve as a substitute technique. The other alternative would have been to revert back to large-size bricks. Why this was not practised is not clear. Of course, Muslim tradition was against it, but the fact that so much of Muslim architecture was executed by local craftsmen makes the argument of 'tradition' somewhat weak. This matter has not been studied and no reference material is therefore available, but it is possible that the whole problem revolves around the fuel supplies. Bricks have to be burnt with fuel, and the scarcity of fuel would very probably lead to a reduction in the size of the brick. This would explain why throughout north India the size of the brick progressively
declined as we come closer to the present. The Muslims, on the other hand, already came from arid areas where fuel was a permanently scarce material and they had, therefore, ready-made solutions to hand. One was to use a small brick in combination with lime mortar. Gujarat, being accessible to supplies of wood, chose the other technique: small bricks associated with woodwork. We shall see later that this latter technique also appears in West Asia.

One final material aspect remains to be examined. What was the quality of the small brick used? Here we have some remarks by experts. George Watt, in his "The Commercial Products of India" (1906), writes, "But if Indian fired bricks have not hitherto borne a very high reputation for strength and durability, it has been upheld that the cause of the inferiority should more often be sought in the process of manufacture than in the material used. A writer in Indian Engineering (August 4, 1900) pointed out that in making bricks by hand it was very difficult to get the edges sharp and well defined ... In India it is usual to manufacture hand-made bricks near the place where they are to be used, and it is highly likely, therefore, that the clay employed is not always the best that could be desired or discovered ..." (16).

One additional reason for the poor quality of bricks was the problem of fuel. Till the coming of the Europeans to India, coal or even charcoal was not used for burning brick. What was used in wood-rich areas was local timber from inferior trees. In Gujarat, on the other hand, wood was considered too precious to be consumed in this way and instead they used the waste products accruing from agriculture. Stavorinus described the making of lime and brick at Surat as follows, "A certain sort of coralline earth, is made use for the former (lime) this they throw together in a heap, mix it, and cover it with cowdung, and set the whole on fire, and it sometimes continues burning for a fortnight. The material of which they make bricks is a clayey earth, which they mould at the spot where it is dug, set them in heaps, and burn them with cowdung. The manipulation of both articles is, however, performed in a slovenly and awkward manner. (17).
Thevenot noted the following, "Brick and Lime are very dear also ... The Houses are covered with Tiles made half round, and half an Inch thick, but ill burnt; so that they look still white when they are used, and do not last ..."

"Now, it is better building in the Indies in the time of Rain, then in fair weather because the heat is so great, and the force of the Sun so violent, ..., that everything dries before it be consolidated, and cracks and chinks in a trice ..."[18].

The above will show the climatic and technical inadequacies of the local environment. Our own field survey showed brick being made even today in many areas with the help of straw, brushwood, dried grass, etc., and the whole process was extremely primitive.

Added to the inadequacy of the brick was the fact that, at least in Gujerat, there was no regular system of brick-bonding employed. This can be clearly seen from the photographs in Illustration. The bricks are simply heaped up in thick beds of mud mortar and it is obvious that such a wall can by itself have no great stability. A wall fully made of mud is extremely strong because all the parts cohere to form a monolithic structure. But when mud and brick are brought into conjunction, the bond between mud and brick is poor, and the resultant wall is far inferior to a fully mud wall. We have ourselves often observed cracks in brick walls due to the load of beams, but not when the same beam rests on a solid mud wall. The weakness of brickwork executed in mud mortar is perfectly clear, and in a multi-storeyed structure this would never be safe with small bricks and relatively thin walls. Woodwork in such cases becomes an absolute necessity. From whichever angle one examines the phenomenon, it is seen that given the absence of lime mortar and large-sized bricks, woodwork combined with brickwork was the only alternative to the pure mud wall.

Now, the combination of wood with brick may have been an independent discovery of the Gujerati craftsmen, or it may have been partly derived from the Indus Valley. But there are some
interesting indications that the technique was far more widespread. We begin the account with that nearest to us in time. Percy Brown reports for the Punjab as follows, "... it may be inferred with some certainty that the pre-medieval architecture of the Punjab was constructed mainly of brick ... And it was brickwork of a remarkably fine quality, the bricks being not unlike those used by the Roman builders, broad but thin ... This brickwork it was the custom to reinforce by means of wooden beams inserted in the walls, so that the buildings were timber-framed ... These brick and timber walls were sloped to provide greater stability, the bettering surface being a survival of an ancient mud brick tradition." (19).

Further back in time we have a description of the Greek house in the pre-Christian era, "Timber was now used in the composition of walls as well as of roofs. In the countries south and west of the Black Sea, a single method of building became practically universal. Walls rested on a substructure of undressed stone, strengthened with timber, above which came a timber framework, with vertical posts tied in to the roof and panels between filled with crude or kiln-baked brick. Above all, this device afforded the structural elasticity so necessary in a region continually subject to earthquakes. It was one which only deforestation could render impractical, and despite the latter has survived to the present day ... But from Crete and Greece to the inland cities of Anatolia and Syria, it dictated the main principles of design ..."(20).

We may here insert a more contemporary opinion of the woodwork seen in Bombay by George C.M.Birdwood in 1880, "... and the houses of the rich in the old streets of Bombay, built before the domestic architecture of the people was affected by Portuguese influences, constantly remind you, especially in their woodwork, of the houses of the Ionian Greeks ... and the woodwork is the essential framework, the solid skeleton, of native houses in Bombay, and is put up complete before a stone or brick is placed on it." (21).
Going further back in time beyond the Greeks we have Henri Frankfort describing Syrian architecture of 1000 B.C., "It (the palace of Niqmepa) used wood, moreover, in a most lavish fashion... The building stands on stone foundations... Next follows a construction of wood and bricks: beams, sometimes as much as a foot in diameter, are laid flush with the inner and outer faces of the walls, and support short timbers lying across the wall at intervals of two to four feet. The interstices are filled with sun-dried bricks. These are followed by more beams supporting timbers, and so on. The use of wood is extravagant and out of all proportion to its usefulness."(22).

Now, this part of Syria was then ruled by a tribe known as the Mitanni, about whom Frankfort writes, "We have stated before... that the Mitanni were new comers in the north Syrian plains who spoke an Indo-European tongue, worshipped Indra, Mitra, and Varuna, and imposed political unity on the natives."(23) (See Ill.782a for this type of ancient Syrian construction).

Going back to about 2200 B.C. we hear of Anatolian architecture as described by Seton Lloyd, "Early Bronze Age architecture and building construction varies little from district to district. Stone foundations are used and an upper structure, either of stone or of mud-brick inserted as panels of filling in a framework of timber posts and beams. The upright posts which occur at intervals of two to three feet in the walls are attached to the ends of roof-beams above, giving a form of stability which is intentionally kept slightly elastic as a precaution against earthquakes."(24). He then describes Troy of 2300 B.C., "Even the protective outer walls with their powerfully buttressed sub-structures, were plentifully reinforced with wooden beams, while the houses in themselves probably had upper storeys lightly built of plaster in a framework of timber. Closely clustering together over narrow alley-ways, they must have resembled the 'half-timber slums of Jacobean London..."(25).
The key-word here is 'timber reinforcement' which appears again and again as a refrain in all the descriptions. Timber-reinforcement is structurally different from half-timbering (see our three categories, page 35). Half-timbering is a wooden framework with the hollow spaces filled in with brick; timber reinforcement is a brick structure with timber inserted at intervals. The two are diametrically different. The timber reinforcement described above is identical in character with our third category of wooden construction, and it is also the kind of woodwork found in the Indus Valley in a few examples. It is the same technique which re-appears in the Punjab. Thus, from ancient Anatolia and Syria in the west, through the Punjab and down to Gujarat in medieval times, we find an identical technique of wooden construction being employed. (Only ancient Persia remains to complete the arc, but here no evidence is recorded of timber reinforcement. That may be due to a greater quantum of destruction). Given this picture, may we not conclude that the origin of this technique goes back to West Asia? And the reason for it becomes even more convincing: the danger of earthquakes! Timber reinforcement served to protect the brickwork from being rent apart by earthquake forces.

A word of caution is here needed. The fact that an apparently Aryan tribe, the Mitanni, ruled over parts of Syria at that time does not necessarily mean that it was an Aryan method of construction. Frankfort himself draws no such conclusion. The technique was West Asian, only the temporary rulers were Aryan. But it does provide us with a link. It directly links the technology of that area and of that time with a community which later certainly prevailed in India, and thus makes the transfer of the tradition very likely. But it equally makes it very possible that the technology of woodwork was transmitted by traders who travelled by sea from West Asia to the Gujarat coast. As we have already seen, the use of woodwork in Gujarat seems to be definitely linked with the sea-trade.
A most dramatic proof of such a link is provided by the architecture of ancient Abyssinia. K.A.C. Creswell, the great scholar of Islamic architecture, was looking for the origins of a style of construction which existed in the Ka'ba at the time of Muhammad, namely alternating layers of stone and timber, and found it in Abyssinia. He describes this, "The walls, with their door- and window frames, are constructed in a most characteristic fashion, well shown in fig. 3... the walls are built of small rough stones... set in an earthy mortar. At intervals horizontal timbers are let into the walls, one on the outer and one on the inner face of the wall at each level. These are crossed by numerous short, round logs which pass through the wall... They are slotted below so as to fit down over the longitudinal beams which they clamp securely together, so strengthening the whole fabric of the wall." (26).

A glance at the figure quoted by Creswell, and shown in our Ill. will reveal the extraordinary similarity of the wooden construction to that described throughout this study. The way in which bonding timbers and door-frames are constructed are identical for 11th century Abyssinia and medieval Gujarat. (Compare the Abyssinian door-frame with Ill. 187, 490 ). There can be no possible doubt that both are made by carpenters who are following identical traditions. While the general custom of using bonding-timbers could have been borrowed by traders who visited these two regions, the exact identity of carpentry details could not have been transmitted in this way. For this to happen we have to posit that the actual workmen of one region went by sea and worked in the other. Knowing the great amount of sea travel which prevailed between medieval Gujarat and West Asia, this is not at all improbable.

We may now sum up the evidence collected above. It shows that the technique of timber-bonding was wide-spread in all of the countries bordering the Arabian Sea. Much of this area also happened to be earthquake-prone and timber bonding was certainly used to combat it. The coastal areas in this whole region were
known to have had mutual contacts via shipping from very ancient times, and there are at least two clear references to wood being exported from Gujarat to West Asia, one in the Periplus, the other for the Ka'ba. It seems therefore quite obvious that this bonding-timber tradition spread from one area to the other, and even if we do not know its precise origin, there is no doubt that historically it appears earliest in the Anatolian region. When we come to studying the details of wooden construction, we shall see that the technique of timber-bonding is one which suits a region poor in wood, such as much of West Asia and Saurashtra, while our other two wooden categories represent areas rich in wood, such as the Deccan. It should be here added that Gujarat is not earthquake-prone, so that this is certainly not the reason for its presence.

One speculative point remains to be mentioned in this connection. Was Gujarat settled by migrating Gurjars coming from elsewhere? Scholars are not all agreed upon this point and the evidence is inconclusive. But there is some evidence to show that there were a people calling themselves Gurjars in parts of Punjab and Kashmir, and their descendents are still there; further, there were a people calling themselves Gurjars in Gujarat. So that a kind of link is established between north-west India and Gujarat. When it is considered that the north-west was the entry route of numerous migrations into India whose movements are well documented, then it does not seem unreasonable to assume that the Gurjars also used this route. If so, it would tell us that these migrants brought the bonding-timber tradition into Punjab and Gujarat from areas further to the west.

(c) Association of Stone with Wood: In the above discussion we have looked at woodwork used in association with brick. Here it is necessary to consider, very briefly, the association of wood with stone. So far as Gujarat is concerned, this occurs only in Saurashtra (including Kutch). It represents the third of our three wooden techniques. And there is no need now to discuss it at length, because the manner in which wood is used with stone
is identical with the manner it is used as timber-bonding with brick. What is more fundamental is to understand the use of stone in the first place, and then to seek for an explanation for the presence of wood. In other words, we have to examine not how wood was used (it was used as bonding-timber), but rather why it was used at all. The analogy with the earthquake danger does not help us here.

Now, Saurashtra is characterized by an arid climate and a rocky terrain with very little fertile soil. As a result, the most ready material available for house building was natural stone. But cutting and dressing stone was an expensive affair, and this manner of procuring stone could never have led to a general domestic architecture. What the inhabitants used instead was rubble stone, i.e. stone picked up loosely from various outcrops or river sites, and this laid in mud mortar became the common material of construction. A wall made in this way was, however, very weak because the stones did not fit each other accurately. Nevertheless, such walls were made of necessity but never went beyond ground floor. For multi-storeyed structures the stone was regularly quarried and properly dressed and used as 'ashlar'. Here the close fitting of joints ensured stability even though mud mortar was used, plus the thickness of walls and the larger size of the stones gave the necessary strength. In all cases where good quality of stone was used this technique was adequate. But in large parts of Saurashtra the stone found is poor, as the following will show.

D.F.Wadia in his "Geology of India" writes of Porbender stone as being composed of, " ... calcareous wind-blown sand ... the whole compacted into a white or cream-coloured, rudely bedded freestone. The rock known as Junagadh lime-stone is a typical aeolian limestone ... It is mainly composed of fragments of calcareous shells (of living species) cemented by lime. About 6-12 per cent of foreign particles of the Gjiiner igneous rocks into the composition ..." (27).
Another description from Watt is, "Thus in Guzerat a more or less calcareous rock ... (Milcolite) ... has a very wide distribution. Its greatest development is in the Gir hills ... As a building stone it is admirably suited for some purposes, but is said to be incapable of sustaining pressure".(28).

The above shows that much of the stone is a conglomerate made up of fragments cemented together with lime and the information given by Shri V.C. Mehta, ex-Chief Engineer (29), confirmed the fact that such stone cannot be used for beams or joists. In addition it has the serious defect that it weathers poorly. Upon constant exposure to climatic effects the cementing material disintegrates and the embedded fragments fall out leaving the stone pitted and gouged. This can be seen in Ill.722.723, and it is obvious that such an unstable stone cannot produce a stable wall even when dressed and laid in courses. In all such cases bonding-timbers have to be added, and the greatest use of this was found in the Mahuva-Bhavnagar belt. In other areas the bonding-timber was absent, but nevertheless below all major beams wooden columns embedded in the wall were placed so as to take the load and prevent it coming upon the weak stonework. All openings were spanned by wooden beams because the stone could never have supported the load. We thus find the strange situation that an area rich in stone (as Saurashtra is) yet had to introduce extensive woodwork in its construction because the stone was quite inadequate. This, then, was the reason for the combination of wood with stone.

The above conclusion raises some interesting points. If no substantial building could be constructed without the assistance of woodwork, how were the houses made in an area deficient in good wood? The obvious answer would be: wood was imported. But that would mean that until such imports were ensured, no better class houses could be made. In other words, a significant domestic architecture could only have arisen once the supplies of good timber were ensured by a regular import by sea. Once again we come up against the same linkage: namely an association of domestic architecture with wood which is in turn associated with
imports by sea! This would indicate that Saurashtra could 
not have been settled in a major way until and unless imports 
of timber were first organized. Further, that such settlements 
would naturally tend to be near the coasts so as to benefit from 
the imports. The historical evidence seems to support this, 
because the important ancient settlements, such as Vallabhipur, 
Junagadh, Somanath-Patan, are all near the coast. The most 
interesting point would then be to discover whether those who made 
the settlements were the same people as the ones who organized 
the sea-trade. If that is so, then it would mean that the whole 
colonization of Saurashtra would have been by a sea-faring people. 
There is nothing improbable about this.

A review of the whole theoretical situation in regard to 
timber-bonding, as discussed above, shows that wood was introduced 
in every single case where the supporting wall was weak (or 
thought to be weak with regard to earthquakes), and this gives us 
the clue to its presence. Timber appears as a stiffening or 
reinforcement material added to a supporting mass. Now, it is well 
known that when a wall gives way under a load of force, the nature 
of the stress which causes the damage is tension. A compressive 
stress is usually well resisted even by weak walls; it is tension 
which is dangerous. Tension arises in walls due to various 
reasons, but principal among them are unequal settlement of the 
foundations, unequal loading, and earthquakes. Timber is a 
material which is well known to be very resistant to tensile 
forces and therefore its introduction in such tensile situations 
is perfectly logical. The timber frame holds the walls together 
and prevents both cracks and buckling. Now, it seems to us that 
while all this is logical, the idea of using timber in this 
way could not have arisen a priori merely as a result of forethought. 
Nor would it have arisen as a result of experience spread over 
many years. Many defects of construction exist, such as the 
leaking of flat roofs, but they do not lead to changes in 
techniques precisely because they occur so slowly and are spread 
out over so many years that they become virtually accepted as
inevitable. It is the sudden, dramatic event which stimulates change in established technique. It therefore seems to us that the only event which fits this conclusion is the earthquake. So that it is the earthquake zone of West Asia in which we may expect the technique of timber-bonding to have arisen. The centre of this zone is approximately modern Jugoslavia, Turkey and Anatolia, and this would serve as the locus of diffusion of the technique to all the neighbouring regions. Other areas, though being earthquake-free, would acquire the technique because the structural problems which they had were in some way related, namely a tendency for walls to give way suddenly. Or, alternatively, the technique could have been actually taken by migrants to areas where similar structural problems existed. In either case, the locus of origin of the idea would remain the same. So far as Gujarat is concerned, the locus being in West Asia is perfectly in accord with the known contacts which Gujarat has all along had with that area. We shall in the following examine some other possibilities; and this brings us to quite a different technique of using wood, namely half-timbering. Let us see what half-timbering is in the Indian context.

(d) Half-timbering: There is in South Gujarat (and elsewhere) a technique of wooden construction which is quite different from timber-bonding. This has already been briefly described along with the three techniques mentioned earlier (page 35), and its essence lies in the fact that timber is placed vertically and embedded within walls. What is the origin of this practice?

In areas rich in straight timber the raw material, wood, is itself so cheap and plentiful that it automatically becomes the preferred material of construction. The method of using wood is as follows. Long, straight posts are prepared and put into holes previously dug in the earth; the holes are then filled in and rammed to make the posts firm. Each post has a forked upper end and over this are placed purlins for the roof, the purlins then carry rafters and over these come various kinds of roof-coverings such as grass or thatch or tiles. The intermediate species
between the posts are closed in with bamboo or reed wattle and coated with mud, the whole technique being called wattle-and- daub. This is an extremely primitive technique of construction and is known the world over, so that it is not specific to either Gujarat or India. But it is specific to wood-rich regions, and South Gujarat is one such region. The indigenous tribal groups in South Gujarat (and also in the hilly and forested fringes of eastern Gujarat up to Danta) use this technique for house construction extensively, and the main ethnic groups are the Kolis and the Bhils.

Now, when a tribal group becomes economically more prosperous, it also seeks to improve its house design in order to acquire a higher social status. In South Gujarat the manner in which this is executed is that, while the framework of timber posts is left intact, the wattle is gradually replaced with brick walls in mud mortar. The brickwork not only occupies the intermediate spaces between columns but also surrounds the posts partially and embeds them within its mass. The result is a composite wall made up of embedded wooden columns in which one face of the column is visible in the surface of the wall. This, then, is half-timbering in our context. Superficially it seems to resemble timber-bonding, except that while the former is vertical the latter is horizontal, but in actual fact the two have quite different structural origins. In timber-bonding the wall comes first and the wood is added to the wall as reinforcement; in half-timbering the wood comes first and the wall is added to the woodwork in order to produce a more solid appearance. The timber-bonding is a structural necessity, the brickwork added to the timber frame is not.

There is a possible misunderstanding which must be here clarified. It may be thought that the simple timber frame is sufficient only for a single-storeyed building, and that the desire for a multi-storeyed building made the addition of brickwork compulsory. This is only partially true. The simple timber frame, as seen in South Gujarat, has a very great height equal to that of a two-storeyed building. Within its height is fitted in a
spacious loft equal to a full upper storey, so that it is virtually a two-storeyed structure. It is these large structures which were seen by Tavernier and described as 'barns'. There is thus no compelling need for brickwork up to this height. But for buildings taller than that, of three and four storeys, wooden framing alone is insufficient and brickwork has to be added. The technical reason for this inadequacy is as follows.

The height of the timber frame is limited by the height of the available tree. In order to make a structure higher than this, it would be necessary to join one wooden frame vertically onto another wooden frame, but if this is done then the resulting structure is completely unstable. The principal weakness of timber construction lies in its joints. Vertical timber joints are technically unsound because there are no means to effectively bind the joint together. Brickwork solves this dilemma. It will be remembered that earlier on it was mentioned that timber posts are embedded in the earth for stability. Now, if to this primary frame secured in the earth, there is added a horizontal layer of beams/ joists (not roof-purlins) so as to produce a flooring, and if this flooring is then made up of a thick layer of earth, we get a flooring at first floor level which is again composed of earth. Into this earth we can again embed a fresh lot of timber posts in order to produce the upper floor (first floor), and if this process is repeated we get a multi-storeyed structure. But, even here the timber joints between each set of posts and beams/joists is not so strong as to be adequate against incidental lateral pressures. To secure this, one has to introduce at selected points a thick brick wall well tied in to the timber frame to give the 'mass' necessary to resist lateral pressures. Only now is the multi-storeyed structure rendered stable. This, then, is the technical reason why brickwork (or any other equivalent heavy material) becomes essential for the timber frame. In this sense we may say that the addition of brickwork to the South Gujarat timber frame was dictated by the desire for higher buildings, but that was not the original motivation.
South Gujarat even today has a majority of two-storeyed houses using timber frame and brickwork, and the latter is not structurally necessary. The real original motive for adding brickwork was status.

Another possible misconception relates to the question of security. It may be thought that wattle was replaced by brick for the sake of greater internal security. This question of security will be discussed at greater length when we come to settlement patterns (Chapter four); here we may only say in advance that while security was important to a few urban residents possessing wealth, it was not so for the majority of rural people, and yet they have changed over to brick walls wherever possible. Of course, the ability to add brickwork implies the possession of some wealth, and the two certainly go together. But it should not be automatically assumed that additional wealth had to be partially invested in improving the domestic house through brickwork. Security and stability could easily have been achieved by the addition of a mud wall. The mud wall, as we saw, is stronger than the brick/mud mortar combination, and in fact we have observed many Thakur houses of mud in many areas. The change over to brick was not primarily dictated by security, but by the desire for status. It was the same reason which motivated, in North Gujarat, the change from mud to brick. In South Gujarat the normal transition should have been from wattle to mud-wall to brick-wall; instead we find everywhere the jump from wattle to brickwork. It is quite obvious that the mud wall, even though otherwise adequate, looked too similar to the wattle-and-daub combination to serve the new social purpose of status. And by this devious path we get a wood-and-brick architecture.

One clear proof of the development having taken place as described above is the fact that the richer South Gujarat houses all continue to have internal embedded columns placed exactly according to the pattern prevailing in the primitive wattle-and-daub house. There was no need for columns to be so placed,
for the solid brickwork could have taken over some of the functions of these columns, but the tradition was too strong and the result is that the number of embedded columns is far in excess of what is structurally required. The domestic architecture of South Gujarat has thus a profusion of embedded columns compared to that of North Gujarat. Much of this style eventually penetrated northwards, but that belongs to a later chapter. What may be mentioned here of special interest is that this technique of using wood prevailed in all the Maratha houses seen by us, and it was found also in the Maratha houses of northern Maharashtra as described by M.S. Mate (30). The famous Shanivar Palace at Poona was in the same style, as the foundations show. This would indicate that it was a Deccani tradition, but it must be emphasized that it was not brought into South Gujarat from that region. This technique is fully indigenous, and all that has to be said is that it is a technique which is wide-spread and common to a much larger area than South Gujarat. There is no need to seek for its origins in any one zone because the manner in which timber was used is so simple that it could with ease have been independently discovered by people anywhere.

This brings us to a topic which has already been touched upon earlier, namely the combination of wood with mud, and some additional remarks are now required to complete the subject.

(e) Association of Mud with Wood: We have seen that the mud wall needs no timber reinforcement to give it stability because of the monolithic and adhesive nature of the clay. On the other hand, timber framing by itself also does not need any buttressing by mud so long as it is not given an unusual height. Both these conclusions lead to the third conclusion, namely that wood and mud are used separately but never together. This is a very surprising conclusion because both are primary and primitive materials and one would have expected their simultaneous use in domestic architecture. With a few exceptions, to be shortly discussed, the two materials never appear together in Gujarat as
load-bearing elements. We have an architecture in mud and an architecture in wood, but never an architecture of mud-and-wood. The reason is, of course, now evident: both mud and wood are in themselves so adequate that neither needs the addition of any other material for stability. But there seems to be one further aspect of the matter.

In general, good alluvial mud and good, straight timber rarely occur together in the natural state! If we refer back (page 44) to the kind of landscape in which straight timber grows, we shall find that it is well-drained, hilly terrain which encourages straight growth. Hilly terrain does not have good alluvial soil. Conversely, alluvial soil does not produce good, straight timber. The fact that these two primary materials do not occur together in the free state could be one very important reason why they also do not appear together structurally. Otherwise what we should have seen is a framework of wood encased within a mud wall. This never occurs in Gujarat.

Where wood and mud do, however, appear together, the situation is as follows. We have found houses made of timber framing and walls of mud, but the walls were placed well away from the timber framing. In this case, the real load-bearing function is carried out by the timber, and the mud merely acts as a screen. In no case do mud and timber both behave structurally. It is curious why the mud wall is not made to encase the woodwork, for that would be quite logical structurally. One reason may be this. Woodwork is prone to attack by white-ants, and these insects find their way in best of all within mud. A mud wall in contact with woodwork would soon be subjected to their destructive attacks, and the damage would not be visible until too late. Assuming that the damage was noticed in time, and the woodwork was intended to be replaced, this would again be very difficult to do because the whole mud wall would have to be first dismantled. Repairs of this nature are not practical. It is far more sensible to keep woodwork and mud separate, firstly to avoid easy access to white-ants, secondly to make repairs easier. When the woodwork stands by itself, damaged portions can be easily
exchanged with fresh parts. These two reasons operate to keep timber and mud structurally apart. It will thus be seen that there are many reasons for this strange phenomenon.

The one interesting exception to the rule comes from examples found by Sir Aurel Stein in Central Asia dating from about the 3rd century A.D. Here he observed houses made of timber frames encased in mud, and within the mud was wattle. In other words, the structure was timber and wattle, but the mud was applied so thickly as to form an encasing wall. And the reason given for this kind of structure is that the wind forces in that region are so powerful that they completely erode a mud wall in a short time. "It is obviously ground once closely occupied by houses which, being built only with walls of sun-dried bricks or stamped clay ... could not hold out so long against wind-erosion as the superior timber-and-wattle built structures of the well-to-do." (31).

The situation is quite clear. The ordinary people had houses of sun-dried bricks and these were soon eroded by wind; the richer people, i.e. those who could afford timber, added the timber and wattle as a reinforcement to the mud wall to enable it to better resist erosion. Now even if erosion took place, the house would not collapse. The illustrations in the book by Stein show rows of closely placed posts jutting starkly out of eroded mud walls, looking like skeletons amid the debris. The places mentioned are in ancient Khotan, and these were Buddhist settlements of the Kushan period. Once again, we find a link with India, and that too with the north-west. These settlements were along ancient trade routes which also led to West Asia. The zone of woodwork used as a reinforcement is thus extended northwards. The only reason why mud was at all used and not brick was due to the shortage of fuel. And, again, we find that the presence of the wood is dictated by the weakness of the wall.
Having analyzed the above themes individually, we must now revert to one subject already touched upon which has a controversial aspect, namely the use of small bricks in Gujarat. We saw earlier that all reports agree that over the centuries the size of brick tended to steadily decrease until in Muslim times it became unusually small and 'biscuit-like'. And it was the use of this small brick coupled with mud mortar which compelled the use of timber-bonding. Now, if this evidence is accepted, then the use of timber-bonding in Gujarat must coincide and originate with the advent of Muslim rule. Such a conclusion had been tentatively put forward earlier on (page 88), and the main difficulty which it raises is that it breaks the link which woodwork seemed to have with the pre-Muslim periods such as, for example, the Chalukyan or even the Indus Valley. It raises many additional problems of an insoluble and contradictory nature: Why should Muslim rule induce a whole society to abandon the size of its traditional brick; particularly in Gujarat it was the other way round, namely that the Muslims took over indigenous techniques such as the corbelled dome; again, if Muslim techniques of construction were adopted, then why not lime mortar and the arch; finally, is it reasonable to assume that both the small brick and timber-bonding would be spontaneously adopted when the Muslims themselves did not extensively use the latter?

In our opinion the theory of Muslim introduction of the small brick is not accurate. The archaeological reports show that the size of brick had been decreasing centuries before the advent of the Muslims and quite independent of them, and although no explanation for this strange phenomenon has been provided, it seems that the only possible explanation is the steadily increasing shortage of fuel for brick-burning. The use of inferior fuel would go hand in hand with a decrease in size of the brick, so that irrespective of external influences much of the country would inevitably turn to the use of small bricks. In areas poor in structural wood the small brick would be accompanied by the use of lime mortar, in areas having access to structural wood (such as Gujarat) timber-bonding would arise. This explanation fits in
with all the known facts, produces no contradictions, and it serves to restore the continuity of the wooden tradition of Gujarat with its own past. In other words, timber-bonding and the small brick existed even in pre-Muslim times and was a natural product of the material circumstances.

We may now close this discussion on the theoretical aspects of woodwork and summarize the main conclusions as follows. Woodwork in Gujarat appears in two main varieties: as timber-bonding and as a regular half-timbering (the latter has two sub-divisions, one full half-timbering, the other partial, the difference is marginal and will be explained later). Timber-bonding is a very ancient technique going back some thousands of years and its earliest recorded evidence is found in West Asia. Its prevalence in Gujarat follows two patterns. One, it occurs in areas poor in wood; two, it occurs in areas which had ancient contacts with West Asia. Both these conditions are met with ideally in Saurashtra. The technique of half-timbering occurs in South Gujarat, with an intrusion northwards, and is closely related to the wood-rich areas of the Deccan.

Timber-bonding occurs everywhere only when the wall itself is inadequate with respect to certain unusual circumstances: for example, earthquake forces, wind erosion, inadequate mortar coupled with great height, the need for status. And so far as Gujarat is concerned, such timber-bonding occurs only with brickwork and rubble stone.

Half-timbering occurs because of other unusual circumstances: need for security, greater height, need for status. And in Gujarat such half-timbering occurs again only with brickwork.

The structural characteristic which is common to both techniques is that wood is used in association with brick, so that superficially there is a resemblance. But the structural
behaviour and origins are quite different. To both is common
the fact of height, i.e. it is the multi-storeyed structure
which necessitates the woodwork. And to both is common the
need for status. The use of brick, the additional height, status
—all three characteristics indicate wealth. And now it will
become clear why woodwork is primarily an urban phenomenon in
Gujarat.