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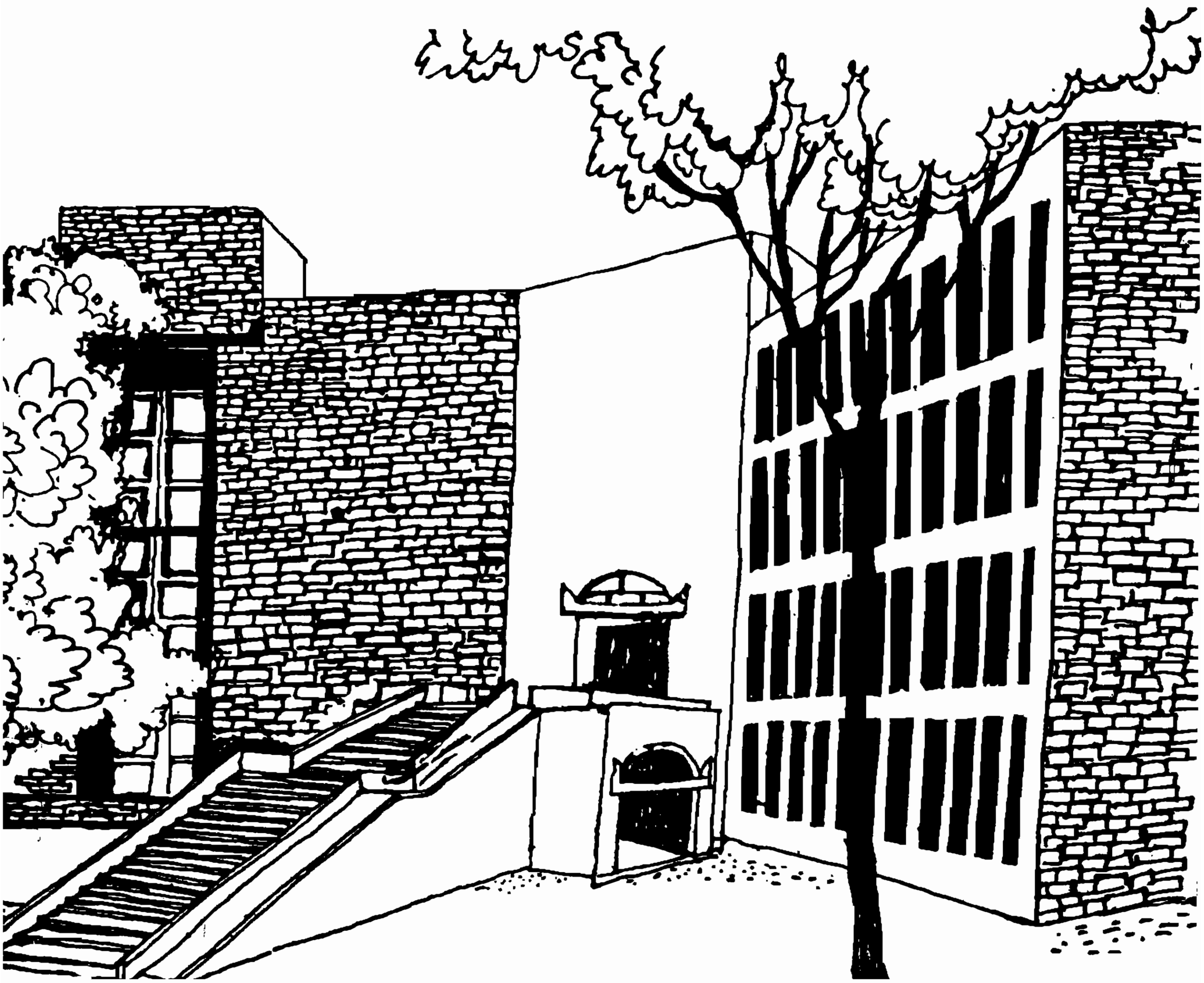

MECHANICAL PROPERTIES OF WOOD CARTON USED FOR LONG DISTANCE TRANSPORT OF TOMATOES

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Mechanical Properties of Wood Carton used for Long Distance Transport of Tomatoes*

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Abstract

Tomatoes are produced and consumed year round. Wood carton is the dominant mode of packaging for produce coming to APMC Market, Ahmedabad from out-of-state. It has been known for long however that wood carton suffers from many shortcomings. It is unable to protect the produce sufficiently against mechanical hazards encountered in transit and handling. Produce gets bruised, dented and generally battered due to vibrations in transport, drops and shocks received in loading and unloading. Our own earlier study indicated that mechanical damages could be as high as 17 per cent in locally grown tomatoes and higher in those brought to APMC Ahmedabad from out-of-state.

Growers are aware of this and have begun to use CFB cartons. However, these cartons are not designed for perishable produce, but for consumer durable like TV, compressor, etc. Our work aims at designing and introducing better cartons for tomatoes. First part of this work, reported in this paper, deals with the mechanical properties of presently used wood carton. The results will be used to develop design concept and specifications of the new carton being designed.

Wood carton was found to have high stacking strength. It deforms 1 to 1.5 mm per 100 kg load. Drop tests indicate however that nail joints begin to loosen after about 6 drops. It can not endure more than about 12 straight drops of 20 cm. Angular drops are equally severe on the carton. Cracks also develop and lengthen with longer sequence of drops and exposure to vibration.

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Introduction

In Ahmedabad, as elsewhere, tomatoes are consumed through out the year. Two crops are grown in the state--one in rainy season and the other in winter. These come to market in September-October and again in March-April. Rest of the time, the supplies came from as far as Punjab, Karnataka, and Maharashtra. Wood carton continues to be the dominant mode of transporting tomatoes. Produce coming to APMC Ahmedabad from out-of-state comes in wood cartons. Growers in Gujarat sending tomatoes to out-of-state locations do so in such cartons. Use of Corrugated Fibre Board (CFB) cartons has just started. But in Gujarat it is limited to short distances only. Moreover, the CFB cartons used are those meant for products like soft drinks, TV, compressors, biscuits, cosmetics, etc.

This new practice suggests that the growers are desirous of finding substitute for wood carton but are not getting the right one. Search for a substitute by the growers, is in line with the findings reported by several workers over the past decade wherein various shortcomings of the wood carton have been brought to light. Our own study **[1]** revealed that tomatoes incurred significant mechanical damages in transit; and that the extent of damage is closely related to transit distance.

Our work aims at designing and introducing in the market, suitable substitutes for wood cartons which tomato growers can use. We also intend to introduce consumer packs in addition to the trade packs. First part of the work deals with study of mechanical properties of existing wood cartons, which is presented here. Although, wood carton has been the focus of several studies in the past, as we shall see presently, its mechanical properties have not been investigated in detail. Accordingly, we made the mechanical properties the focus of this study. We present first a review of literature. It is followed by the results of mechanical testing. Finally, the specification of improved cartons is drawn up.

Review of Literature

Venkatsubbaiah *et.al.* [2] conducted an experiment, in which apple was transported by road from Shimla to Mysore (3000 km) in wood cartons. The aim was to find out the extent of bruising. They reported that produce in cartons that had strong ribbons and wall lining incurred the least bruising. Results confirm the view that bruising is due to collision between fruit and fruit, and fruit and wall. Ribbons and lining cushioned the collision interfaces.

Joshi *et al* [3] compared CFB and wood cartons for transport and storage of mango. Mango was transported by road from Dapoli to New Delhi (2000 km). The aim was to find out the effect of different packaging on quality of fruit on arrival. They reported that CFB of 7 ply, 6 holes and 3 ply CFB honeycomb partition were the best. Fruit transported in these had slower and more uniform ripening, lesser spoilage and physiological losses.

Singh *et* al [4] studied the damages incurred by tomatoes by simulating the road transport on a vibrating table. It was found that the firmness decreased with increase in duration of vibration. A lining of loose paddy straw, both in plastic and wood carton improved the results. Apparently the lining cushioned the fruit-wall interface which is one source of bruising.

Singh et al [5] conducted an experiment, in which tomatoes were transported by road from Amritsar to Jammu (200 km) in wood cartons. The aim of the study was to find out the effect of vibrations on firmness of tomatoes during transportation. Accelerometers were placed at the base of the box as also inside. The frequency range of the instrument varied 0-480Hz. It was found that boxes experienced an acceleration as high as 11.5 g. Tomatoes inside experienced less, 7.5 g. General conclusion was that the firmness decreased as exposure to high accelerations increased.

Singh *et al* [6] studied the performance of wood carton and corrugated fibre board carton for desheri mango. General conclusion was that CFB is economical, light in weight and (better) preserve the quality of fruits.

Kushal *et al* [7] conducted a study on use of new packages for apples. Apples were transported in bamboo-mat, wood and CFB carton by road from Solan to New Delhi (500 km). Bamboo-mat was found more suitable, as it had partitions and absorbed less moisture from the fruit. The implication is that CFB absorbs moisture from the produce which leads to reduction in its strength.

Above review suggests that conventional wood carton is unable to protect the produce adequately in transport. Produce incurs bruising in large and varying degree. This in turn leads to greater spoilage, reduced shelf life, rapid and non-uniform ripening. Changes have occurred in grapes, apple, etc. which are now packed in CFB cartons. Tomatoes however continue to be packed in wood cartons.

It is reasonable to surmise that changes occurred more rapidly in apple, grapes, etc. because these are relatively high value produce and the cost of improved CFB cartons is relatively small part of that, perhaps about 3 per cent. Secondly, loss of quality in apple, grapes is more easily perceived by the consumers as most of these are eaten fresh. As against these, tomato is a lower value produce. Presently those who use CFB cartons, incur nearly 15 to 20 per cent in packaging cost. Tomato is in greater part used as vegetable. Quality loss is less easily perceived. Hence, the growers continue to use the wood carton.

It is also relevant to point out that none of the works cited above draws attention to mechanical properties of wood carton such as stacking strength, ability to withstand shocks during handling and transport, and ability to retain its structural integrity during transit. Its strength is not affected by exposure to moisture.

Wood carton will endure, until cost effective substitute is developed, which retains some of its good mechanical properties. Therefore, we investigated these aspects. These will be necessary input in designing the new substitutes.

Wood Carton: Material and Fabrication

Cartons of three different sizes are generally seen in Gujarat. The most common has outer dimensions (42x30x28 cm), and holds about 20 kg of tomatoes. The other two hold of about 25 kg. Cartons are fabricated at `Box Market' in Behrampura, Ahmedabad. Wood is obtained from timber processors, usually of neem, mango, deodar, nilgiri, etc. It has coarse finish. **Figure 1** shows details of a carton. Box is formed by nailing together 15 slats. A gap of about 5 mm is left between the slats to permit aeration.

Four pieces of a slightly thicker strips are nailed on top and bottom to reinforce the box as well as provide a grip for handling. Box making is a household industry. Everything is done by hand without the use of proper tools. Accordingly, there tends to be variation in dimension, tare weight, firmness of joints and consequently the mechanical strength. For instance, tare weight of 20 kg cartons varies from 2.3 to 2.65 kg. This is due to rough wood and crude fabrications. Small quantity purchase price of these is Rs.15 per piece.

Test Protocol

In the course of its journey from packaging shed of the grower to the retail stores in cities where it is dismantled, a carton is subject to handling abuse (drops) during loading, unloading. It is subject to static loads when stacked in columns in trucks. It is subject to vibrations and dynamic loads induced in the course of road travel. Three types of tests were therefore conducted--drop, compression, and vibration - to simulate the mechanical hazards to which the cartons are usually exposed. Test procedures are based on **[8].**

All cartons used in tests were newly fabricated. In view of the fact that fabrication is crude, lacking in dimensional and weight uniformity, got a larger number made and selected the required number of more homogenous in dimension and weight. Outer dimension of selected cartons was sufficiently uniform at 42 x 30 x 28 cm and weight varied from 2.4 to 2.6 kg. All cartons were climatised prior to test, by storing for 72 hours in a conditioned room where temperature was maintained at 23°C and relative humidity at 50 per cent. Tests were carried out in the laboratory of Core Emballage Limited, Ahmedabad.

Tests were conducted in July 1998. This is not the growing season for tomato in Gujarat. Therefore tomatoes were purchased from APMC Ahmedabad each day for use in tests. Since these were coming from as far as Bangalore and Nasik, considerable bruising and other damage had already been incurred. For use in tests, tomatoes were selected to ensure that these were free from cracks and skin discontinuities. Fruits were also sorted, using an improvised sorter. It consisted of wood template with holes. Tomatoes used in tests were of 2.0 - 2.5 inch equatorial diameter. Although observation on (further) damage to produce during tests were made, these should not be taken to be very realistic in absolute magnitude terms. Focus of these tests was the cartons and not the produce.

Compression test

Empty cartons were placed in between the platens of the BCT machine. As the upper plate moved down, deformation and load were displayed on the read-out panel. Deformation was noted at intervals of 25 kg. Six replications were made for this test.

Drop Test

Authors carefully observed the workers packing tomato at the farms and placing the boxes on trucks, loading and unloading the boxes at the APMC market, Ahmedabad. Also, one day, authors themselves did loading and unloading at the market emulating the workers. After these experiences, it was decided to conduct drop test in two different ways. One set of tests were conducted by dropping filled cartons from a height of 20 cm straight on the steel platform of the drop tester. Another set of tests were done by placing one edge of the carton bottom on the platform and lifting the opposite edge sufficiently so that the bottom made an angle of 25 degree with the platform. Higher edge was then allowed to drop. These are the two ways workers handle the carton while loading and unloading. Drop testing medium at Core Emballage has a minimum drop height of 70 cm. Dropping was therefore done manually. At the end of each drop, structural damages to carton were noted. The amount of fruit burst was also noted.

<u>**Vibration test - Time Censor**</u>

Three filled cartons were placed side by side, simultaneously on the platform of vibrator. One carton was removed after every 20 minutes. Vibratory machine had pre-set frequency (3 Hz) and also pre-set amptitude (15 mm horizontal and 6 mm vertical). Manufacturer claims that one hour on the machine represents 1000 km of road travel. However, it is not certain that this stipulation is applicable to Indian road-vehicle conditions. At the end of test, damages to carton and amount of fruit burst were noted.

Results and Discussion

(a) Stacking Strength

Force deformation graph is shown in **Figure 2**. Deformation was found to be nearly linearly related to the compressive load. Although all the six cartons were visually similar, the behaviour of two of those was slightly different than the four others. Unlike others, these two cartons incurred deformation of 3 mm, just in the first 25 kg load. The other four hardly incurred any deformation with this load. Subsequent behaviour of all the six was however similar. This initial differences was perhaps caused by less tight nailing or other imperfections in fabrication.

During transport, these cartons are stacked six high. Thus, the bottom carton will have on it a static load of about 125 kg. On occasions, there could be some extra load, such as caused by a person sitting on it. Cartons should be capable of resisting a static load of 250 kg without excessive sagging. It is seen from figure 2 that under a load of 250 kg, deformation would not exceed 6 mm. Some workers have indicated that when stacked in a column of normal height deformation should not exceed 10 mm in cartons meant for fresh produce. Wood cartons meet this requirement adequately. Although, cartons could take high compressive loads without complete failure, damages did occur. New cracks appeared from nailing points. Old cracks, propagated further.

(b) Ability to withstand Handling Abuse

Drop test simulates the handling abuse. It is our observation that a carton could be placed and lifted some ten times in its journey from farm to the retailers shop where it is finally opened. A good carton would be expected to preserve its structural integrity through such a sequence of drops. It would also be expected to protect the produce. Damage to carton in drop test was observed in two ways. The length of diagonal of the top face was measured and compared with the original. Appearance of new cracks and further propagation of old one was noted. One carton was dropped 12 times and damages noted after every two drops. Three others were dropped six times each and changes noted at the end of each sequence. Results are shown in **table 1**.

Drops tend to loosen the nails. This shows itself in increase in the length of one or both top diagonals. Sometimes the length of just one diagonal increases, sometimes of both **(figure 3)**. First four to five drops did not make any significant damage to the carton. General conclusion that emerges for drop test is that the best of wood cartons can not retain their structural rigidity beyond 10 to 12 drops. Angular drops are nearly equally severe on the carton as well as the produce. Since, the cartons are meant for single use only, this is good enough. But it would be advisable to improve the joints.

Each fruit was examined for burst and cracks. Fruits that burst or developed skin discontinuity was around 5%.

(c) Ability to preserve its structural integrity in transport

Vibration test simulates the road transport during which cartons are subjected to vibrations. **Table 2** shows the results of accelerated vibration tests. Given the frequency and amplitudes in this particular machine, the acceleration to which the cartons were subjected works out as below.

$$G = \frac{Df^2}{500} \qquad \text{..........(1)}$$

G number of g unit

D displacement of vibration, mm

f frequency = H_z

$$G = \frac{16.15x3^2}{500} = 0.29g$$

This is a rather low. In actual transport, tomatoes are subject to higher accelerations [5]. Nonetheless, a loosening of the nails was observed, indicated by lengthening of the diagonals.

Summary and Conclusion

Wood cartons used for tomatoes were put to drop, compression and accelerated vibration test. Cartons obtained from the vendor were newly made. All cartons were pre-conditioned for 72 hrs before test with temperature maintained at 25°C and relative humidity at 50. Tomatoes used in test were obtained from local APMC market. These had come by road from Bangalore covered a distance of 2000 km. Fruit were already heavily bruised and dented. Tomatoes used in test were selected from the lot. Selected once had 2.0 - 2.5 inch equatorial diameter. Focus of the study was `damage to cartons' and not the produce. Tests were conducted in the lab of Core Emballage Limited, Ahmedabad.

Under compression, wood carton deforms at the rate of about 1 to 1.5 mm per 100 kg load. In other wood under the usual stacking height in truck (6), the bottom carton will deform less than 6 mm. Thus under static loads, the cartons are sufficiently strong. But drop and vibration test reveals the tendency of nailed joints getting loosened significantly to reduce the rigidity of the carts. In the course of its journey, a carton may be dropped by about 10 times, from height of about 20 cm. Drop test reveals that this is about all it can endure. In fact, nail joints became loose in about 6 drops. Cracks also develop on the walls.

Table 1

Drop Test (straight fall)

Sr. No.	Net weight of tomato (kg)	No. of drops	Weight of burst fruit	Carton diagonals(cm)				Physical condition carton
				Before		After		
				1 - 1	*2 - 2*	*1 - 1*	*2 - 2*	
1	18.6	6	386	47	47.5	48	48.5	Cracks increased, nails come out
2	18.6	6	865	47	48	48.8	49.5	
3	18.6	6	1050	47.5	47.6	49	47.8	
4	18.5	12	1280	47.5	48	48.3	48.4	
Drop Test (angular)								
1	18.4	10	850	48.5	49.2	49	49	One side of carton was totally damaged nails come out
2	18.4	10	650	49.5	49.7	49.7	50	

Table 2

Vibration test

Sr. No.	Net weight of tomato (kg)	Removed after (mts)	Weight of burst fruit (gm)	Carton diagonals (cm)				Physical condition of carton
				Before		After		
				1 - 1	*2 - 2*	*1 - 1*	*2 - 2*	
1	18.5	20	100	48.4	49	47.5	47.3	No significant damage to the carton
2	18.7	20	70	48.3	48.5	48	48.5	
3	18.4	40	50	48.3	49	48.7	49	
4	18.5	40	50	47.4	48	48	48	
5	18.4	60	50	47.5	48.5	49	49.5	
6	18.6	60	40	49.2	49	48	49	

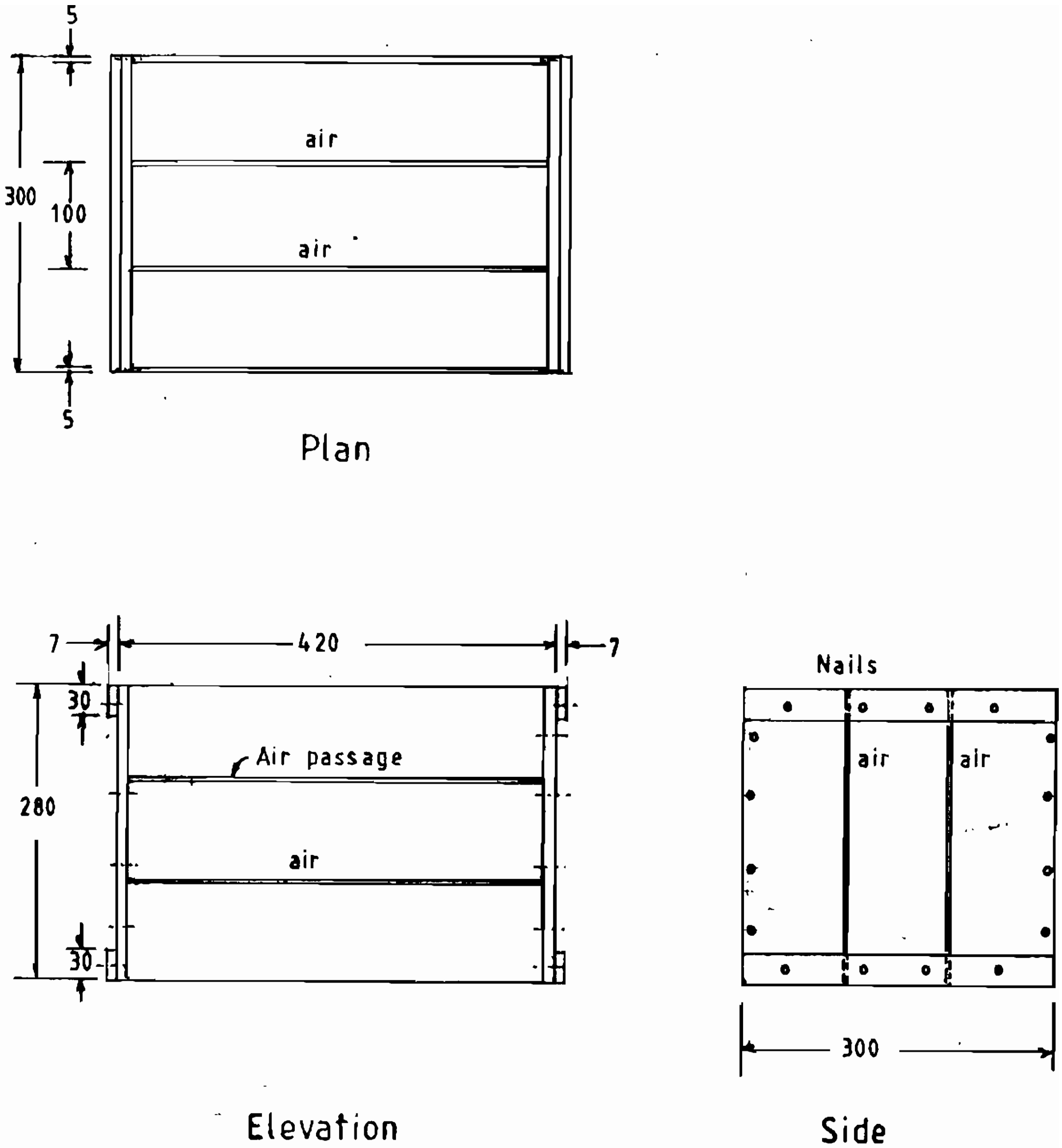

Fig. 1.

All dimensions in mm.

Title: Container Use for Tomato					
Mate: Wood of Mango, Neem etc.					
Drn.	Ckd.	Date	Mate.	Scale	Drg. No.
Ajay		23-6-98	Wood	3 : 20	

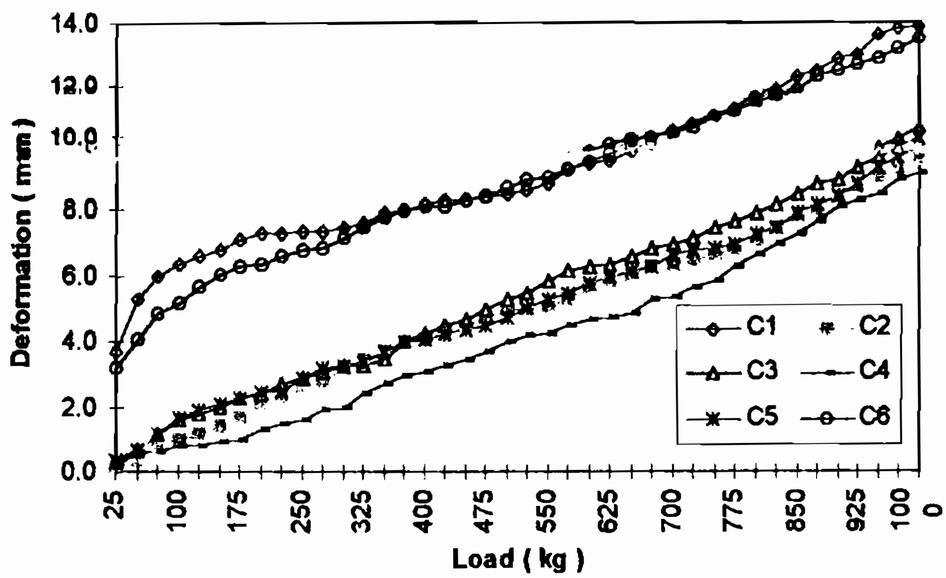

Fig-2 Force deformation curve of wooden cartons

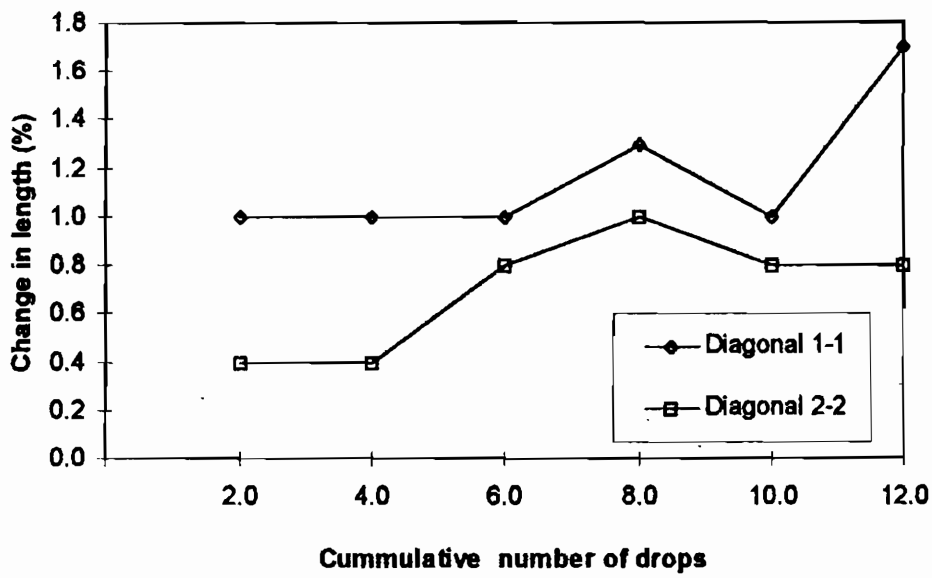

Fig 3 - Change in diagonals due to repeated drops

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