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PANEL ÇEŞİDİ, ARKALIK PANELİ VE FARKLI DUVAR MONTAJI UYGULAMALARINA GÖRE MUTFAK DOLAPLARININ MAKSİMUM YÜK TAŞIMA KAPASİTESİ

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Özet

Bu çalışmada mutfak dolaplarının yük taşıma kapasitesi incelenmiş, deney örneği mutfak dolaplarında malzeme çeşitleri, duvar montaj yeri ve arka panel gibi faktörlerin yük taşıma kapasitesi üzerindeki etkileri araştırılmıştır. Deney örneği mutfak dolapları 1/1 ölçekte hazırlanarak kalıcı deformasyona ulaşılıncaya kadar statik yük altında test edilmiştir. Çalışmada, iki farklı duvar bağlantı noktası, yonga levha (PB), lamine yonga levha (PB-m), orta yoğunluklu lif levha (MDF) ve lamine orta yoğunluklu lif levha (MDF-m) olmak üzere 4 farklı ahşap esaslı kompozit malzeme kullanılarak, dört elemanlı (arkalık paneli olmadan) ve beş elemanlı (arkalık panelli) toplam 48 mutfak dolabı üretilmiştir.. Tüm köşe bağlantıları 4 x 50 mm vidalar kullanılarak oluşturulmuştur. Tüm test numuneleri statik yük altında test edilmiş olup bir yükleme kayışı ile üst panelin yüzeyinden yükler uygulanmıştır.. Sonuç olarak, arkalık paneli olan mutfak dolaplarının, arkalık paneli olmayan mutfak dolaplarına kıyasla iki kat daha fazla yük taşıma kapasitesine sahip oldukları görülmüştür. Mutfak dolaplarının yan panellerden duvara tutturulması için açılı metal konektörlerin yerleştirilmesi, sadece üst panelin değil, tüm yapının daha fazla yük taşımasına yardımcı olacağından; bu bağlantı elemanlarının kullanılması önerilmektedir. Ayrıca, Yongalevhadan üretilen mutfak dolapları, MDF'den üretilen mutfak dolaplarının mukavemetinin 2 / 3'üne sahip olduğu görülmüştür.

Anahtar kelimeler: Arka panel, Yonga levha, Orta yoğunlukta lif levha, Maksimum taşıma kapasitesi, Mutfak dolabı yapısı.

Bu makale, 4. Uluslararası Mobilya ve Dekorasyon Kongresi'nde sunulmuş ve İleri Teknoloji Bilimleri Dergisi'nde yayınlanmak üzere seçilmiştir.

KITCHEN CABINETS MAXIMUM LOAD CARRYING CAPACITY BASED ON PANEL TYPES, USE OF BACK PANEL & WALL MOUNTING POINT CONDITIONS

Abstract

In this study, the maximum load carrying capacity of wall kitchen cabinets structure were investigated. Factors such as material types, wall mounting place and add of back panel on kitchen cabinets and their effect on the maximum load carrying capacity of the whole structure were investigated. Kitchen cabinets were made in 1/1 scale and loaded until failure happened. For this purpose, a total of 48 kitchen cabinets were manufactured, including two different wall connection points, four different wood based panels, namely bare particleboard (PB), laminated particleboard (PB-m), bare medium density fiber board (MDF) and laminated medium density fiber board (MDF-m) which were used for construction of four and five member cabinets (with and without back panel). All corner joints were established by using 4 x 50 mm screws without adhesive. All test samples were tested under static load, loads were applied from the top panel's surface by using a loading strap. According to the results, kitchen cabinets with the back panels compare to the same kitchen cabinets without back panels were able to carry two times more load. Placement of angled metal connectors for attachment of these kitchen cabinets to the wall from side panels and not from the top panel can help the whole structure carry more load and therefor advised. Particleboard kitchen cabinets structures only had 2/3 of the strength of the corresponding MDF kitchen cabinets structures.

Key words: back panel, Particleboard, Medium Density Fiberboard, Maximum load carrying capacity, kitchen cabinets structure.

1. INTRODUCTION (GİRİŞ)

Kitchen cabinets type furniture such as kitchen & storage cabinets are among the most used case structures in our daily life. One may not exaggerate if says that live without them if not impossible, but it is very difficult. They help us organize our daily life not only at our homes or flats, but also at our offices & workplaces. Many woodshops and factories are manufacturing kitchen cabinets to meet the increasing demand of the civilized population. Due to the economic advantage of panel-made vis. massive-wood cabinets, the majority of kitchen and storage cabinets especially in counties with lower income per capita are made by wood based panels such as chipboards or medium density fiberboards. For this reason, increase our technical knowledge about these structures and find solutions of how to make them more durable can be logical reasons to conduct strength study such as this one.

Researchers all over the world have also been studied load carrying capacity of four & five sided cabinet. Some classic studies are reviewed here. Kotas (1958) declared that based on the loading condition, there are two important mechanical methods available for defining stiffness of a case structure. 1) apply a twisting force & 2) apply a diagonal force on the case structure. Based on ANSI/KCMA (1995) test procedures there is also a third way of applying force for determining the

load carrying capacity of a kitchen cabinet which is called "wall mounting method" which have also been used in this study [1] Eckelman & Rabiej (1985) used finite element methods to investigate the deflection characteristics of five sided furniture case. They developed an equation to predict deflection of an unsupported corner of a case which may have both shelves and partition [2]. Eckelman & Munz (1987) studied the effect of the rigidity of the joints on overall case rigidity [3]. Kasal et al. (2008) studied the effect of the screw size and panel type on the load carrying capacity and stiffness of five-sided cabinet. Results proved that MDF made kitchen cabinets were able to carry more load than particle board made cabinets. The effect of screw size on this strength were significant and directly proportional. Their mechanical test set up was based on applying load from one top corner side of the kitchen cabinets while the opposite corner of the top was fixed. The other three bottom corners except the ones that the load was applying above it were supported by roller metal base (twisting force) [4]. Tunay & Tankut (2009) studied the effects of various factors (type of fasteners, material type and thickness) on the rigidity of furniture cases. They concluded that case furniture constructed using glued screw resulted a higher stiffness than similar ones using glued dowels. Gluing of the joining surface can make structures more rigid which will result in less deflection under imposed loads in service [5]. Kasal et al. (2011) studied the effects of material types, screw diameter & length on the ultimate failure load and stiffness of four-sided cabinets. They also used three-point support configuration in their tests [6]. Fathollahzadeh et al. (2013) studied the strength changes of MDF case structures after being exposed to hydro-thermal artificial aging in the lab. He applied twisting force on 1/1 scale four sided cabinets & reported that add edge band to the case structure can effectively increase the ultimate strength of the kitchen cabinets, but cannot prevent ageing [7]. Dzincic et al. (2017) reviewed the factors that affect the rigidity and durability of case-type furniture. They studied other researcher's publication and concluded that there are factors such as panel type & thickness, connector type & its number, connector position along the connecting line, the use and type of adhesive and the joints configuration can indirectly affect the rigidity and durability of a case by directly affecting the strength of its corner joints [8].

In the present study the effect of panel types, availability of back panel and the position of wall mounting placement on the load carrying capacity of case structures have been studied.

2. MATERIAL AND METHOD (MALZEME VE YÖNTEM)

Real size kitchen cabinets each with four corner joints were tested in this study. Half of the experimental samples were constructed by five structural members. They were each consist of a top, a bottom, two sides & a back panel. The remaining half of 48 kitchen cabinets, were constructed with only four structural elements which means without back panel. All four members were from the same material, but back panels were 4 mm thick plywood. Except the differences in type of case construction (with/without back panel), there were two other factors that studied in this research. 1) The effect of wall mounting placement condition (wall mounting connector position) & 2) The effect of wood based panel types. Four different types of wood based panels used in this construction, namely melamine covered particleboard (PB-m), melamine medium density fiberboard (MDF-m), bare particleboard (PB) and bare medium density fiberboard (MDF).

Table 1. Physical properties of the panels utilized in this study (Bu çalışmada kullanılan panellerin fiziksel özellikleri)

Thickness (mm)	Material Types	Density (g/cm³)	Moisture Content (%)
18	PB	0.72	6.64
	PB-m	0.71	6.06
	MDF	0.79	6.20
	MDF-m	0.80	5.57

Table 2. Experimental design configuration (Denme deseni konfigürasyonu)

Wall mounting placement	With/without back panel	18 mm thick panels				
		PB	PB-m	MDF	MDF-m	Total
On the sides of the kitchen cabinets (side panels)	With back panel	3	3	3	3	12
	Without back panel	3	3	3	3	12
On the top of the kitchen cabinets (top panel)	With back panel	3	3	3	3	12
	Without back panel	3	3	3	3	12
Total		12	12	12	12	48

90 degree angle iron connectors as kitchen cabinet wall mounting connections where placed in two forms as 1) in connection with top panel & 2) in connection with side panels. (Fig. 1) Wall cabinet's dimensions were the same as the real size used in our daily life. All 48 samples were 750 mm in height, 300 mm in depth and 840 mm in width. In figure 1 the mechanical test condition and the placement of wall mounting as well as two types of cabinet construction are shown.

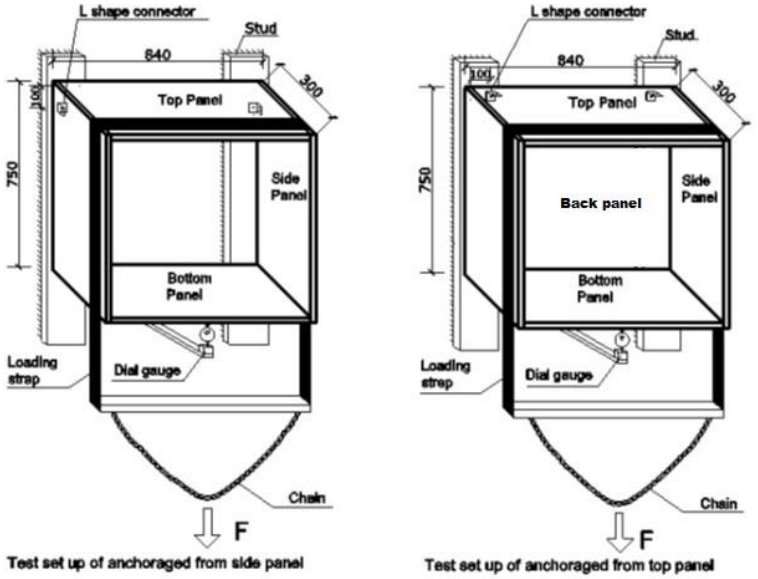

Figure 1. The scheme and test setup of two types of kitchen cabinet that was used in this study (Bu çalışmada kullanılan iki tip mutfak dolabının duvar montaj şeması ve deney düzeneği)

All samples were joined together without adhesive and by only three screws (4 by 50 mm) in each of the kitchen cabinets corner joint. The drilling map is demonstrated in figure 2.

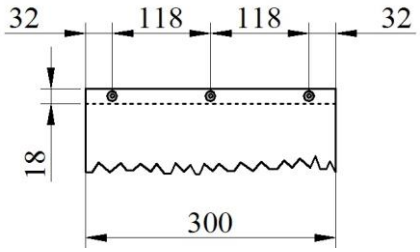

Figure 2. Screws placement of the drilled pilot holes for each screw in the corner joint of the kitchen cabinets used in this study (measurements in mm) (Bu çalışmada kullanılan mutfak dolaplarının köşe birleşim yerlerindeki her vida için delinmiş pilot delik vidalarının yerleştirilmesi (mm olarak ölçülmüştür))

Screws were drilled to the corner of the thickness of side panels. When attaching screws, pilot holes were drilled in to the edge of the side panels. The diameters of the pilot holes were equal to approximately 80 percent of the root diameter of the screws, and depth of the pilot holes were equal to approximately 75 percent of the penetration of screws (Eckelman 1991). Before fasten screws and make the final structure, pilot holes were drilled. Diameter of the drilled pilot hole were defined as 2.5 mm with the depth of 32 mm in the edge member of each corner joint. The back panel member connected to the main body (edge of side panels) with 3.5 by 25 mm screws without application of adhesive.

CONNECTOR SCREW SIZE IS 4X18MM

BACK SIDE SCREW SIZE IS 3.5X25MM

CORNER JOINT SCREW SIZE IS 4X50MM FOR KITCHEN CABINET

Figure 3. Screw types (Vida tipleri)

Three different screws were used to construct and mounth the kitchen cabinets. Those are; while 4x50mm screw was used to construct corner joint of the kitchen cabinet, 3.5x25mm screw used to establish the back (4 mm playwood) panel to the back side of the kitchen cabinet and 4X18mm used to screw the 90 degree angle iron connectors to the kitchen cabinet (Figure 3).

All test samples were stored in climate chamber which was sets to 20 ºC ± 2 and 65 ± 3 % relative humidity for appropriate time prior to measurements and test in order to avoid moisture content variations effect on measured properties. Physical and mechanical properties of the test samples were evaluated in accordance with the procedures described in ASTM D 4442 (ASTM 2001b) [10] and ASTM D 1037 (ASTM 2001a) [11], respectively. All tests were performed on a 50 kN capacity universal testing machine at a loading rate of 6mm/min. Load applied (fig. 1) by a loading strap which passed over the top and along the two sides of panel and meet under the kitchen cabinet where the loading head of the universal test machine was present. Test setup was established upper place of universal testing machine because of loading was loaded in vertical direction to the kitchen

cabinet. After two parallel 100 by 100 mm studs had attached to the profile main frame by nuts and bolts, test samples were mounted on the studs by using two L-shape metal fixtures and screws.
This study was carried out to examine the ultimate failure load of 1/1 scale normal wall unit kitchen cabinets under the static test. The procedure of the test was suggested by ANSI / KCMA (1995) [12]. It was assumed that since the applied load was in balance (fig. 1), In the tests, it was designed in which kitchen cabinets were fixed on the studs to keep the samples during the test, and thus expected that the failures will have been occurs on the corner joints instead of separation of the entire kitchen cabinet from the studs. There was only one dial gage needed to measure the deflection in vertical direction after applying the load on the kitchen cabinets. This dial gage was placed in the middle line under the bottom panel as shown in fig 1. Load was continued until a failure or full separation of members occurred at the corner joints. Failure modes, maximum load carrying capacity and deflections of each individual kitchen cabinets were recorded for further reference and analysis.

3. FINDINGS (BULGULAR)

3.1. Evaluation of data

A three factor analysis of MANOVA general linear model procedure was performed for individual data both load carrying capacity and stiffness to analyze main effects and their interactions on load carrying capacity values of four & five-sided kitchen cabinets were statistically different at the %5 significance levels. Summary of MANOVA results are provided in Table 4.

Table 4. Summary of ANOVA results for Load carrying capacity of kitchen cabinets (mutfak dolaplarının yük taşıma kapasitesi için ANOVA sonuçlarının özeti)

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F VALUE	P VALUE
A	3	335368.896	111789.632	36.6363	0.0000
B	1	1494249.187	1494249.187	489.7037	0.0000
AB	3	64626.563	21542.188	7.0599	0.0009
C	1	1952536.687	1952536.687	639.8962	0.0000
AC	3	70401.729	23467.243	7.6908	0.0005
BC	1	190890.188	190890.188	62.5596	0.0000
ABC	3	411.562	137.187	0.0450	
ERROR	32	97642.667	3051.333		
TOTAL	47	4206127.479			

Table 4 showes meaningful result of the study that the least significant difference (LSD) multiple comparison procedure at 5% significance level were performed to determine the mean differences of load carrying capacity of corner joints values of four & five sided kitchen cabinets tested considering the ANOVA, according to results mentioned above.
Findings of this study shows that regardless of having pack panel or being covered by melamine veneer, MDF kitchen cabinets structures are generally 30% stronger than PB kitchen cabinets structures (Table 5).

Table 5. Maximum load carrying capacity of kitchen cabinet made of wood based panels (Ahşap esaslı panellerden yapılmış mutfak dolaplarının maksimum yük taşıma kapasitesi)

MATERIAL TYPE	X	HG	LSD VALUE= 45.34 X: VALUE AVERAGE
MDF-M	659.3	A	

MDF	637.3	A	(KG) HG: HOMOGENEOUS GROUP
PB	550.8	B	
PB-M	447.0	C	

Average load carrying capacity values of kitchen cabinet corner joints are given in Table 5. Test results showed that maximum load carrying capacity of kitchen cabinet corner joints were significantly affected by the panel types. In general, Kitchen cabinets were constructed of MDF-m and MDF showed the highest values. It can be explained that the significant difference between MDF-m & PB-m is based on the material types. It is also can be assumed MDF-m density higher than PB-m density. The samples constructed of MDF-m was carried higher loads than those of the samples constructed of PB-m & PB. The samples constructed of PB-m carried the lowes load among the samples constructed the other 3 panel types.

Table 6. Mean comparisons of maximum load carrying capacity of four and five sided kitchen cabinets (Dört ve beş kenarlı mutfak dolaplarının maksimum yük taşıma kapasitesinin ortalama değerlerinin karşılaştırması)

MATERIAL TYPE	X	HG	LSD VALUE= 30.06 X: VALUE AVERAGE (KG) HG: HOMOGENEOUS GROUP
FIVE SIDED FURNITURE CASES	775.3	A	
FOUR SIDED FURNITURE CASES	371.9	B	

Table 6 shows mean comparisons of five sided kitchen cabinets values of four-sided kitchen cabinets tested with respect to the load carrying capacity. According to test results, the five sided kitchen cabinets yielded considerably higher load carrying capacity compared to the four-sided kitchen cabinets. The LSD value of 30.06 N/mm was calculated. In general, five sided kitchen cabinets were found to have a greater effect on load carrying capacity than four-sided kitchen cabinets. As it is shown in Table 6, five sided kitchen cabinets shows the highest value of load carrying capacity. According the tablel load carrying capacity values of the five sided kitchen cabinet is 48 % more than the four sided kitchen cabinet.

If considering both the effect of back panel and melamine cover on the sheets on the maximum load carrying capacity of the whole structure; except for the case of bare MDF which the difference in load carrying capacity in its samples with back panels is 1.8 times more than the one without back panels, for the rest of the kitchen cabinets this difference is about 2 times more which is outstanding. For kitchen cabinet of melamine veneered MDF with back panel compared to the same panel without back panel this difference is even 2.4 times more. The higher density of MDF panels can be one reason for this difference. This shows that the effect of adding back panel to increase the maximum load carrying capacity of the kitchen cabinet structures is high and meaningful (Table 7).

Table 7. Mean comparisons of maximum load carrying capacity of kitchen cabinet considering the material types and existence of back panel (Malzeme çeşitleri ve arka panelin varlığı dikkate alınarak mutfak dolabının azami yük taşıma kapasitesiyle karşılaştırılması)

MATERIAL TYPE + EXISTENCE OF BACK PANEL	X	HG	
MDF-M + WITH BACK PANEL	900.2	A	LSD *VALUE*= 64.12 X: VALUE AVERAGE (KG) HG: HOMOGENEOUS GROUP
MDF + WITH BACK PANEL	859.3	A	
PB + WITH BACK PANEL	735.8	B	
PB-M + WITH BACK PANEL	605.8	C	
MDF + WITHOUT BACK PANEL	459.3	D	
MDF-M + WITHOUT BACK PANEL	374.3	E	
PB + WITHOUT BACK PANEL	365.8	E	

PB-M + WITHOUT BACK PANEL	288.2	F	

On the other side the effect of wall mounting positioning in kitchen cabinets on the maximum load carrying capacity of the whole structure was another question in this research. Results in table 6 give us a brief idea that placement of 90 degree angle iron connectors as the kitchen cabinets wall mounting connections is better to be done from the sides and not from the top panel (Table 8).

Table 8. Kitchen cabinets maximum load carrying capacity affected by wall connector position (Mutfak dolapları duvar bağlantı konumundan etkilenen maksimum taşıma kapasitesi)

WALL MOUNTING POINT	X	HG	LSD *VALUE*= 30.06 X: VALUE AVERAGE (KG) HG: HOMOGENEOUS GROUP
SIDE PANEL	750.0	A	
TOP PANEL	397.2	B	

Table 8 shows mean comparisons of load carrying capacity of tested all kitchen cabinets anchorage point of L-shape connector to wall. The LSD value of 30.06 N/mm was calculated. Results showed that the highest values of the load carrying capacity were obtained with connector which anchored from the side panels while the lowest values of the load capacity were obtained with connector which anchored from the top panel.

The first type connecting (from side panels) give the kitchen cabinet 1.8 times more load carrying capacity. If we consider melamine veneer factor on this statistical study (Table 9) then we can observe that except for the kitchen cabinets constructed of bare MDF, which the maximum load carrying capacity of them in those kitchen cabinets that were connected to the wall from side panels is 1.6 times of the ones that connected from the top panel, but for the rest of kitchen cabinets this difference can reach to two times. This is meaningful and considerable therefor connect kitchen cabinets to the wall by placement of connectors on side walls can be advised.

Table 9. Kitchen cabinets mean comparisons of maximum load carrying capacity affected by material types and wall connector position (Mutfak dolaplarını, malzeme tiplerine ve duvar bağlantı konumlarından etkilenen azami yük taşıma kapasitesinin karşılaştırılması)

MATERIAL TYPE+MOUNTING POINT	X	HG	
MDF-M + SIDE PANELS	890.5	A	
MDF + SIDE PANELS	785.2	B	
PB + SIDE PANELS	739.0	B	LSD *VALUE*= 64.12
PB-M + SIDE PANELS	585.5	C	X: VALUE AVERAGE (KG)
MDF + TOP PANEL	489.3	D	HG: HOMOGENEOUS GROUP
MDF-M + TOP PANEL	428.2	D	
PB + TOP PANEL	362.7	E	
PB-M + TOP PANEL	308.5	E	

The highest load carrying capacity were obtained from the MDF-m, test samples that under the static load and connected from the side panel to the wall, while the lowest values of the load carrying capacity were obtained from the PB and PB-m test samples which mounthed from the top panel for the LSD value 64.12 N/mm. (Table 9).

Table 10. Mean comparisons of maximum load carrying capacity of four/five member kitchen cabinet considering the connection type to the wall (Mean comparisons of maximum load carrying capacity of four/five member kitchen cabinet considering the connection type to the wall)

MOUNTING POINT + NUMBER OF PANEL	X	HG	LSD *VALUE*= 45.34 X: VALUE AVERAGE (KG)
SIDE + FIVE SIDED KITCHEN CABINET (WITH BACK	888.7	A	

PANEL)			HG: HOMOGENEOUS GROUP
TOP + FIVE SIDED KITCHEN CABINET (WITH BACK PANEL)	661.9	B	
SIDE + FOUR SIDED KITCHEN CABINET (WITHOUT BACK PANEL)	611.4	C	
TOP + FOUR SIDED KITCHEN CABINET (WITHOUT BACK PANEL)	132.4	D	

The sicnificant difference among side panel, top panel, five sided kitchen cabinet and four sided kitchen cabinet can be explained based on the back panel (five sided kitchen cabinet). It also can be assumed that back panel (playwood) has higher production quality. The samples constructed of Side panel of five sided kitchen cabinet (with back panel) showed the highest values. Table showes that generally, four sided kitchen cabinets (without back panel) carried out lower values than those of the other samples. Moreover, the lowest values of the load carrying capacity were obtained from the top panel + four sided kitchen cabinet (without back panel) test samples for the LSD value 45.34N/mm. (Table 10).

4. CONCULUSION AND DISCUSSION (SONUÇ VE TARTIŞMA)

4.1. Failure Modes

Similar types of failure modes were observed in the kitchen cabinet corner joints in this study. All corner joint failures occurred approximately between 60 to 90 seconds in the tests. Corner joints were separated slowly rather than suddenly. Failures of the corner joints for kitchen cabinets that were mounted with L-shape connectors to studs from top panels and side panels demonstrated deformations around direction of the screws as created split maximum 40mm radius circular influence zones in the PB, PB-m, MDF, MDF-m kitchen cabinets. However, the kitchen cabinets mounthed from side panels to the studs showed deformations as breaking of connector screws in MDF and MDFm samples and as splits around L-shape connectors of the PB and PB-m samples. Because, L-shape connector screws were broken, the cases which anchored from side panels slipped downward. This situation can be explainad that the significant difference between MDF,MDF-m & PB, PB-m is based on the material types. It is also can be assumed MDF, MDF-m density higher than PB, PB-m density. The samples constructed of MDF, MDF-m was carried higher loads than ones the samples constructed of PB-m & PB.

While deformation characteristics of the kitchen cabinets occure around of back panel screws for the five sided samples, during the tests, the fractures occurred on the underside of top panel on the without back panel samples for the PB, PB-m,MDF-m, MDF samples.

Results indicated that five sided kitchen cabinets yield higher load carrying capacity than those of four sided kitchen cabinets. Also, it was determined that, among the materials, MDF and MDF-m showed significantly higher load carrying capacity than ones PB and PB-m. The five sided kitchen cabinets yielded considerably higher load carrying capacity compared to the four-sided kitchen cabinets. Load carrying capacity values of the five sided kitchen cabinet yield 48 % more than the four sided kitchen cabinet. According to construction type, the highest load carrying capacity were obtained in the MDF, MDF-m, PB and PB-m test samples that under the static load and connected from the side panel to the wall, while the lowest values of the load carrying capacity were obtained in the all test samples which mounthed from the top panel.

Table 9 shows us a more practical information. If one for aesthetic reasons use four sided cases structures for example in the living room or elsewhere to hold heavy decorative objects or to keep books and magazines organized then it is strongly suggested that the kitchen cabinets attach to the wall from its side panels and never from the top panel.

Results of this research show that add back panel in construction of kitchen cabinets from wood based materials can greatly affect its maximum load carrying capacity and therefor strongly advised. In real practical industrial production there are various materials and connecting methods that can be used to attach pack panel to the whole structure. There are needs for more research about connecting methods of back panels to the main body structure which can be done by interested researchers such as studying the effect of material type, material thickness and connecting methods of the rigidity and maximum load carrying capacity of kitchen cabinets type structures that are widely used in our life.

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