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PERFORMANCE OF ANCHORED VENEER ON STUD BACKUP

John Chrysler[1]

ABSTRACT

The provision for veneer cladding has been in the Uniform Building Code (UBC) since the first edition, published in 1927. The concept of masonry veneer is simple, yet the performance of masonry veneer can be marginal if basic, fundamental guidelines are ignored. In this paper, successful attachment methods, as well as attachment methods that are inadequate are presented. Additionally, methods to prevent water penetration into and through the masonry veneer will be addressed.

INTRODUCTION

The West Coast of the United States is a delicate seismic region where the Pacific plate meets the North American plate at the San Andreas fault. Populous Southern California lies on the edge of the Pacific plate and is shattered by numerous seismic faults. Many of these faults have yet to be discovered.

The City of Los Angeles is home to 3½ million residents. The population of greater Los Angeles exceeds 10 million. In order to support the daily activity of the population, millions of buildings have been constructed, with masonry veneer commonly used as a cladding. Occasionally, seismic activity imposes unusual lateral forces on the veneer.

On the morning of January 17, 1994, the Northridge earthquake tested the structural effectiveness of the Uniform Building Code. Ground accelerations between 0.50 g and 1.00 g were not unusual (Goltz, 1994), and the Tarzana Nursery recorded free field ground accelerations of 1.82 g horizontal and 1.18 g vertical. There was widespread damage to masonry veneer, and much of the damage could have been avoided.

[1]Executive Director, Masonry Institute of America, 2550 Beverly Boulevard, Los Angeles California, U.S.A. 90057-1085

THE ANCHORED VENEER SYSTEM

Current UBC defines veneer as a nonstructural facing of brick, concrete, stone, tile, metal plastic or other similar approved material attached to a backing for the purpose of ornamentation, protection or insulation. Figure 1 shows a typical brick veneer system with a wood stud backup. This system is frequently applied to residential construction.

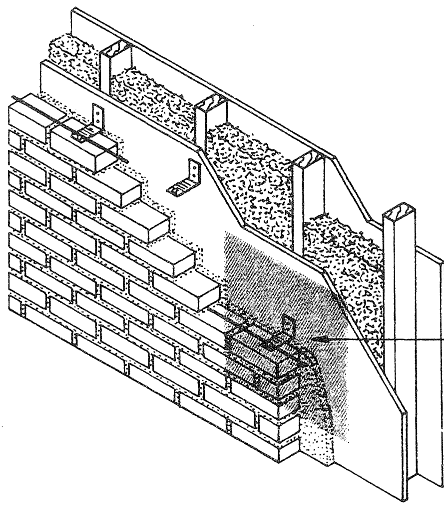


Fig. 1—Brick Veneer/Wood Stud System

Of the empirical veneer provisions in the code, the single most important seismic rule is that the anchored veneer and its attachments shall be designed to resist a force equal to twice the weight of the veneer. A typical masonry veneer system will withstand wind and seismic loading when the veneer weight and the capabilities of the attachment system are known and the design follows the above rule.

Calculation of the brick veneer weight is relatively simple. For an average brick, the veneer will weigh about 49 kg/25.4 mm/m^2 (10 pounds per inch per square foot) of veneer as shown in Fig. 2 and Table 1.

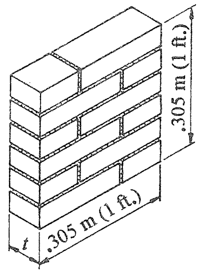


Fig. 2—Dimensions of Brick Veneer for Weight Calculation

Table 1—Weight of Veneer with Known Thickness

Thickness, *t*	Weight or Mass
25 mm (1")	4.5 kg/0.1 m^2 or 49 kg/m^2 (10 lb/ft^2)
51 mm (2")	9.0 kg/0.1 m^2 or 98 kg/m^2 (20 lb/ft^2)
76 mm (3")	13.5 kg/0.1 m^2 or 146 kg/m^2 (30 lb/ft^2)
102 mm (4")	18.0 kg/0.1 m^2 or 195 kg/m^2 (40 lb/ft^2)

An additional requirement for anchored veneer constructed in Seismic Zone Nos. 3 and 4 is wire, minimum 9 gauge, 3.76 mm (0.148 inch) laid in the bed joints of the veneer and engaged in the veneer tie for a positive attachment. This keeps the veneer system together in the event of a major earthquake.

For all veneer systems, anchoring ties are required for every 0.19 m^2 (2 square feet) of wall area. Given a 102 mm (4 inch) brick veneer system, and tie spacing at every 0.19 m^2 (2 square feet), the individual veneer tie must be able to withstand 355 N (80 pounds) of force. Under seismic loading, the lateral force could be either tension or compression.

Most veneer system designs engage a metal tie or metal wire to join the veneer to the backup system. The code limits the minimum size of a metal tie to 22 galvanized sheet gauge, 0.76 mm (0.030 inch) by 19.1 mm (¾ inch), or wire of a 3.76 mm (0.148 inch) , 9 gauge diameter. Tensile strengths are well above 3,450 kPa (500 psi), with only 550 kPa (80 psi) required, however, deformation of a corrugated tie will frequently occur with loads of less than 355 N (80 pounds).

Compressive strength values are also important, and a typical 22 gauge corrugated tie will deform under compression at about 20 N (5 pounds) force The cost to upgrade the quality of the tie is only pennies per 0.1 square meter (square foot), and the benefits are exponential.

Manufacturers of veneer ties can provide test results for their product and only ties that are capable of withstanding both tension and compression lateral force of twice the weight of the veneer should be used.

VENEER SYSTEM ATTACHMENT

The veneer system must be securely attached to the structural backup system. Typical veneer backup systems are structural masonry, concrete, metal studs and wood studs.

Commercial applications of veneer generally use steel stud or masonry as backup. Concrete is occasionally used. Veneer systems that engage steel stud as the backup system are normally attached with corrosion resistant self tapping screws.

In Southern California the screw attachment to the metal stud performs very well under intense seismic loading. There were no widespread failures of upgraded attachment systems as a result of the Northridge Earthquake.

There is also controversy on the adequacy of this screw attachment system to metal studs (Grimm, 1993), which is not addressed here.

WOOD STUD BACKUP

The use of brick veneer in residential construction frequently interfaces with wood studs. In order to keep construction costs at a minimum, corrugated brick ties are nailed into the stud with 6d nails, [D = 2.51 mm (0.099 inch), L = 51 mm (2 inches)], one nail per brick tie. Under the best of conditions, this method does not comply with code.

To understand the capabilities of nails driven into wood studs, it is appropriate to investigate the information contained in Chapter 23 of the UBC. Section 2340 contains the information relating to nails and spikes. The section refers to UBC Table 23-III-FF, which contains information on Specific Gravity of wood members, and Table 23-III-GG for withdrawal design value. Portion of these tables are listed in Tables 2 and 3.

Table 2—Specific Gravity for Douglas Fir (from UBC 23-III-BB, FF)

Species	Specific Gravity, G
Douglas fir-larch	0.50
Douglas fir-larch (north)	0.49
Douglas fir-south	0.46

For analysis, Douglas Fir was chosen since the specific gravity, G, values fall in mid range for the species listed. Once the specific gravity is established, the nail withdrawal value can be determined. For Douglas Fir Larch (G = 0.50), the nail withdrawal for a 6d nail with 45 mm (1.75 inch) penetration is 185 N (42 pounds). This value is well below the required 710 N (160 pounds), which is twice the weight of the veneer for 0.19 m^2 (2 square feet). The use of two nails per tie would satisfy a pullout requirement of 355 N (80 pounds), which would be adequate where 1 tie is installed for each 0.09 m^2 (1 square foot). As a practical matter, the mason is not aware of the importance of two nails, and would consider one to be satisfactory.

Positive anchorage, namely, using a screw to fasten the veneer tie or the track for the veneer tie system into the wood stud, yields much higher pullout design values. Using the same G value as above, a *single* 6d screw produces a withdrawal value of 17.2 N/mm (98 pounds per inch), or 760 N (171 pounds) considering a penetration of 44 mm (1.75 inches). A common 8d screw [D = 4.17 mm (0.164 inch), L = 51 mm (2 inches)] with a 44 mm (1.75 inches) penetration gives a withdrawal value of over 900 N (200 pounds).

Table 3—Nail Withdrawal Design Values (from UBC 23-III-GG)

Nail Withdrawal Values, N/mm (pounds per inch)				
	Diameter, D			
Specific Gravity, G	2.5 mm (0.099") (6d)	2.9 mm (0.113") (8d)	3.3 mm (0.128") (10d)	3.4 mm (0.135") (16d)
0.50	4.2 (24)	4.9 (28)	5.4 (31)	5.7 (33)
0.49	4.0 (23)	4.6 (26)	5.3 (30)	5.4 (31)
0.47	3.7 (21)	4.2 (24)	4.7 (27)	4.9 (28)
0.46	3.5 (20)	3.9 (22)	4.4 (25)	4.7 (27)

Table 4—Wood Screw Withdrawal Design Values (from UBC Table 23-III-CC)

Wood Screw Withdrawal Values, N/mm (pounds per inch)					
	Diameter, D				
Specific Gravity, G	3.5 mm (0.138") 6d	3.8 mm (0.151") 7d	4.2 mm (0.164") 8d	4.5 mm (0.177") 9d	4.8 mm (0.190") 10d
0.50	17.2 (98)	18.7 (107)	20.5 (117)	22.1 (126)	23.6 (135)
0.49	16.5 (94)	18.0 (103)	19.6 (112)	21.2 (121)	22.8 (130)
0.47	15.2 (87)	16.6 (95)	18.0 (103)	19.4 (111)	20.9 (119)
0.46	14.5 (83)	15.9 (91)	17.3 (99)	18.7 (107)	20.0 (114)

An argument against the use of screw attachments is that the action of installing a screw is too time consuming. Given today's technology, a portable, rechargeable drill is readily available at nearly every construction site. Once the mechanic is acclimated with the cordless drill, he or she will find that the process is actually easier than pounding a nail, and, only one screw will easily produce the required empirical code value.

METAL STUD BACKUP

Attaching a hat channel track to metal studs as a connector for the veneer tie is a very popular design concept. Metal screws are used to fasten the channel to the steel stud, and the tie is inserted into the channel giving the system flexibility to move relative to the structural elements of the building. Figure 3 shows a typical hat channel/steel stud design.

Installing a dovetail channel on a steel stud is not recommended, since the channel can spread, thereby allowing the ties to disengage from the anchoring system. The use of dovetail slots in concrete is an excellent approach to a veneer system with a structural concrete backup, as the concrete prohibits the spreading of the dovetail channel.

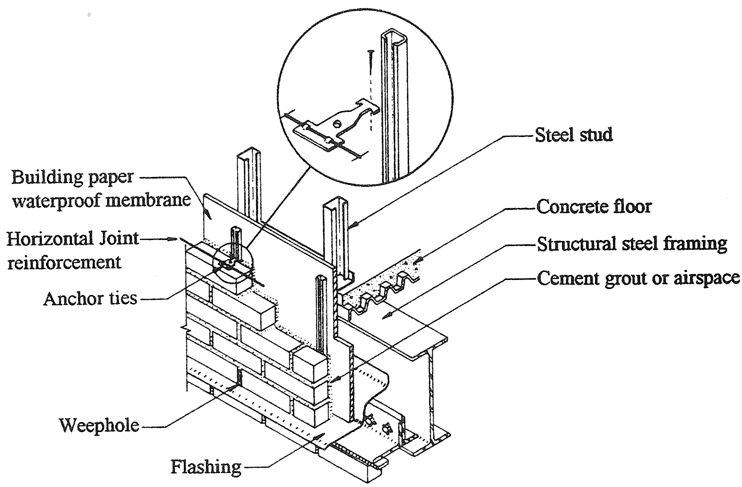


Fig. 3—Hat Channel Anchoring System on Steel Stud Backup

Ingenious masonry veneer anchors are provided in BIA Technical Note 28B. Two of these designs are shown in Fig. 4.

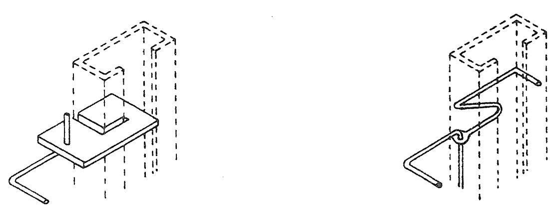


Fig. 4—Masonry Veneer Ties for Steel Stud Backup

The Northridge Earthquake exposed many incidents of code violations relating to all types of construction. Some veneer code violations included insufficient ties anchoring the veneer; a hat channel system that was attached to stucco; and no horizontal reinforcement to hold the veneer together.

Two items revealing damage that might have been controlled are corners and no provision for movement due to expansion, shrinkage or earthquake.

CORNER ISOLATION

Ideally, the corners of veneer should be isolated. Providing movement joints within close proximity of each side of the corner can accomplish this isolation. As a compromise, providing an expansion joint to one side of the corner will isolate the walls from each other. Isolation as shown in Fig. 5 will minimize the stresses due to thermal expansion and seismic activity.

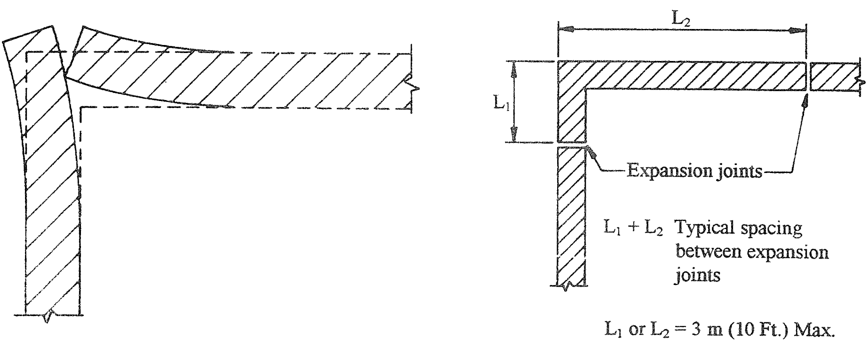


Fig. 5—Movement Joints at Corners

VENEER EXPANSION

The initial 9.1 m (30 ft.) of veneer can be constructed on a noncombustible foundation, and the veneer above should be supported by shelf angles on top of the initial 9.1 m (30 ft.). Brick veneer expansion will occur and Fig. 6 provides the a detail that will accommodate vertical expansion.

The spacing of vertical expansion joints to accommodate horizontal movement on a solid wall should not exceed 9.1 m (30 ft.) with 6.1 m (20 ft.) recommended (BIA, 1991). Consideration is given to openings, such as doors and windows, and the analysis can become quite complex.

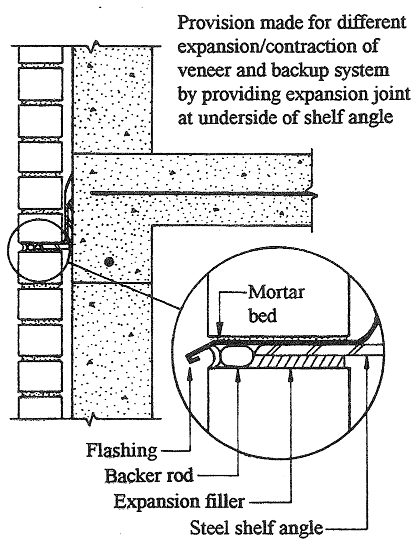
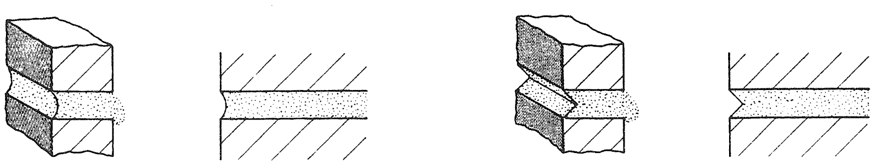


Fig. 6—Anchored Veneer with Provision for Expansion

Also popular, and permitted by code, is an airspace between the veneer and structural backup. This airspace or cavity is beneficial from an energy standpoint, and provides a mechanism for the drainage of any moisture that penetrates the veneer.

MOISTURE PENETRATION

The best defense against water penetration through the veneer is proper detailing and good workmanship. Figure 7 shows two recommended tooled joints, the concave joint and the "V" joint. Tooling seals the mortar surface that is tightly pressed into the brick. Joints such as struck joints and raked joints are not recommended since the joint surface allows more moisture penetration. Raked joints also form a ledge on the horizontal surface of the brick allowing water to collect on that ledge.



a) Concave Joint

b) "V" Joint

Fig. 7—Concave Joint and "V" Joint

Since a certain amount of moisture is assumed to penetrate the veneer, a design that drains the moisture through the airspace between the veneer and the backup will prevent the moisture from finding the inside of the building. This design includes gravity that carries moisture to the bottom of the cavity, impermeable flashing that prohibits moisture from migrating to the interior of the building and weepholes to drain the moisture.

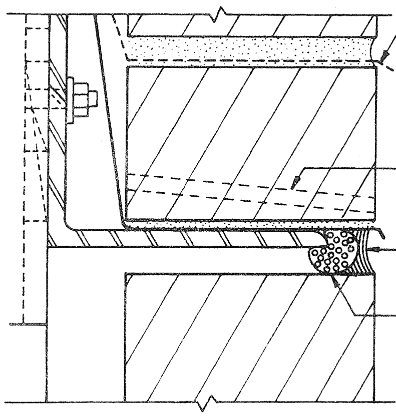


Fig. 8—Drainage Detail at Shelf Angle

SUMMARY AND CONCLUSIONS

The design and construction of masonry veneer is based primarily on experience, performance and empirical design according to the current Uniform Building Code. Analysis of the performance of veneer when intense seismic loads are imposed reveals that veneer constructed in accordance with the present code performs well.

Many of the failures observed in the Northridge, California earthquake were caused by veneer not constructed in accordance with current code guidelines. The spacing of ties must not exceed maximum given code values, and the tie must demonstrate a strength capable of resisting twice the weight of the veneer in both tension and compression. Additionally, the tie must be anchored to the backup in a manner that avoids failure.

Moisture that penetrates the veneer can be collected and returned to the exterior with proper detailing and construction of the veneer system.

The use of tested design concepts can integrate the age old beauty and durability of clay masonry with the residential and commercial buildings of the 21st century.

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