# PLASTIC MEDIA - WHERE’S THE BEEF?
## Avoiding Trickling Filter Media Collapse

John R. Harrison, PE, MS

JRH Consulting
971-563-7471     wwixjohn@gmail.com

*ABSTRACT: In 1974 the cost of plastic trickling filter media ranged generally from $2.00 to $3.50 per cubic foot. In 1997 the cost for plastic media is nearly the same as it was 20 years ago. Why hasn’t the cost of plastic filter media risen dramatically, and are there issues involved that consulting engineers should be aware of or warned about?*

**Photo 1: Warning**

*Presented is a discussion of changes in media manufacturing and on the testing of media. Some of these changes have resulted in confusion as to appropriate specification language for procuring plastic media. The result has been that deficient media was installed at some trickling filter plants. Suggestions are made in this paper as to appropriate specification language for procuring plastic media. Today, there should be no concern that trickling filter media does not have sufficient plastic “beef” and strength o assure a 20-year life.*

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From 1960 through 1980 there were few changes in media configuration or specification language. However, in the early 1980’s two changes occurred which are of major concern to engineers involved in specifying plastic media. The first change was the introduction of the short-term (approximate 2-hour) test for determining the minimum allowable bearing strength of a plastic module. Prior to 1982 plastic vertical flow (VF) media had been specified principally by specifying minimum sheet thickness (from 18 to 27 mil) and requiring that media conform to a 96-hour bearing capacity test with an allowed 2% deflection at 760 lbs/ft$^2$ at a test pressure of 75° F. Another common specification item in 1974 was that module weight was to be no less than 2.1 lb per ft$^3$ or 33 lb per module (2 ft x 2 ft x 4 ft bundle of fastened sheets).

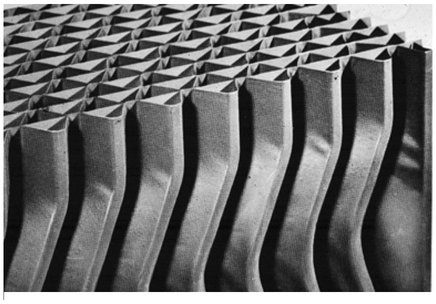


**Photo 2: VF PVC Module**

The second major change which occurred from 1982 to 1984 was the active promotion of cross flow (XF) media as a replacement for VF media. The introduction of XF media brought on a series of concerns as to whether traditional specification values were appropriate for the slanted-corrugated sheets versus the alternating flat and vertically corrugated sheets. Of primary concern was the possibility of solids buildup or partial plugging with XF media, which could add to the live load of the media. There was also a need to account for the corrugation process which includes stretching sheets so that the “after forming” thickness may be only 60 to 70 percent of the “before” forming or flat sheet thickness.

Variations in the success and quality of plastic modules supplied from the early 1980’s through mid 1990’s is illustrated by comparing media at three different facilities. Table 1 presents the data from these facilities, where the media was supplied by the same manufacturer. In 1982 the testing of traditional VF media (Table 1* - Facility A) using a 96-hour test resulted in a fairly substantial media containing slightly over 34 lbs of PVC per module of dry fabricated product. The introduction of XF media (Table 1 - Facility B), and the use of the 2-hour or short-term test with allowance of a 1.25 percent deflection, resulted in a reduction in PVC weight to 25 lbs per module. Even with this reduction in module weight and sheet thickness, the media at Facility B has performed satisfactorily for nearly 15 years.

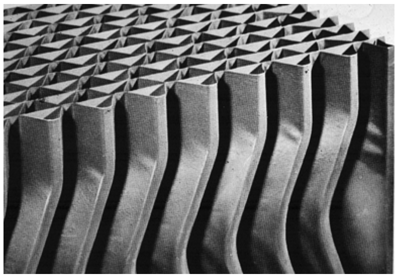


Photo 3: XF PVC Media

However, the media at Facility C was installed in 1992 and collapsed within 5 years. The reduced module weight and sheet thickness at Facility C are the primary suspected causes of failure. Other suspected contributing factors to filter media failures have been:

1. Poor solids capture prior to the biofilter
2. Wastewater containing fouling characteristics
3. Improper use of media with irregular geometric shapes (cross flow and random)
4. Non-uniform media support systems, and
5. Poor fabrication and installation problems.

This paper discusses engineering design choices which are critical in avoiding problems related to the primary causes of media collapse.

## PRIMARY CAUSES OF COLLAPSE

In the mid 1970’s plastic self-standing media was made almost entirely of fastening alternating flat plastic sheets with corrugated plastic sheets. Manufacturing was done by only one or two companies within the United States and material data sheets readily identified both the properties of the individual PVC sheets and the weight and

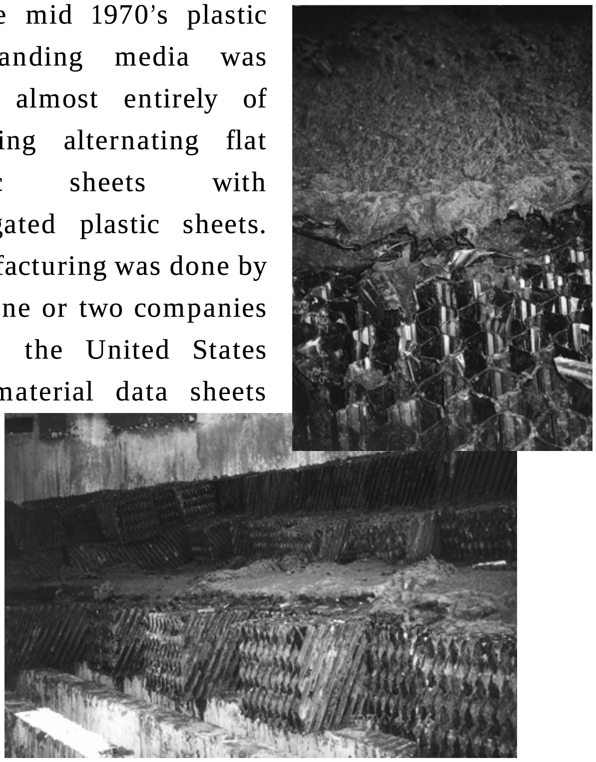


Photo 4: Collapsed Media Layer

bearing strength of the fabricated modules. A typical module (2 ft x 2 ft x 4 ft) was specified to weigh greater than 2.1 lbs per ft$^3$ and (claimed some product data sheets) could withstand a 96-hour compression test with less than 2% deflection with a bearing load of 760 lbs/ft$^2$ at 75° F. Many engineers did not require confirmation testing because of the time and expense of performing the long-term test. If requested, most media manufacturers submitted results from a short-term 2-hour test specifically performed on media to be supplied for that particular project. The 2-hour test had not been standardized but could be correlated to the 96-hour long-term test.

By the early 1980's a new short-term (2-hr) test was formally introduced at a wastewater conference by Jean Mabbott of B.F. Goodrich. By the mid-1980's most consulting engineers were aware of the need to require specific testing of media and included specification language associated with the short-term test. Unfortunately, media of inadequate strength may have been supplied where the engineering specifications did not properly address the following issues.

Photo 5: Deflection on Module Surface

## Allowable Deflection

With the 96-hour test, a 2 percent deflection had historically been allowed with vertical media. When considering deflection it is important to recognize that the original 2 percent allowance was associated with a media whose corrugated open vertical flute was controlled by a wave with minimum height of 1.5 to 1.75 inches. When Mabbott introduced the short term test in 1982, a 1.0 percent deflection was recommended for testing purposes so that not too much plastic material would be deformed or otherwise obstruct the vertical flute opening and inhibit biological soughing.

With the introduction of XF media, the wave height has been generally reduced to 1.25 inches and the previous vertical flute has been tilted to provide a break for water that might otherwise fall vertically without intimate contact. Some engineers failed to heed or understand the potential need to use less than a 2 percent deflection criteria on media tests. The need for a reduced allowable deflection in the bearing test results from: a) reduced wave height, b) change in media geometry, and c) a 48-fold (96 hr:2 hr) reduction in testing time. Those engineering firms who used a 1.0 to 1.25 percent deflection in their 2-hour bearing strength media specification generally obtained media with more plastic "beef" than those who retained a 2% deflection criteria.

## Sheet Thickness and Module Dry Weight

With VF media in the 1970's one major manufacturer offered three sheet thicknesses: 27 mil (extra heavy), 23 mil (heavy), and 18 mil (standard). Their forming (bending or corrugating) process was done so that there was no difference between the sheet thickness "before" or "after" forming.

However, with the introduction of XF media most manufacturers produced corrugations by thermoforming which stretches the media so that consideration should be given to both "before" and "after" forming sheet thickness. The "after" forming thickness is a direct ratio of the surface area of sheet material prior to and after the forming of a module. For example, with a standard shaped module made of 19 sheets with a flat surface area of 16 square feet per sheet, the total uncorrugated or "before" forming surface area would be 304 square feet. If the supplied or "after" fabricated media contains 30 $ft^2$ per $ft^3$, then the after forming area is 480 $ft^2$ (30 $ft^2/ft^3$ x 16 $ft^3$) and the area ratio is 0.63 (304 $ft^2$/480 $ft^2$). Therefore, if the plastic modules are formed from 22-mil sheets, the after forming thickness would be approximately 12.7 mils (0.63 x 22 mil).

Requiring a minimum before forming thickness of 24 mils has been one method of assuring the media has sufficient PVC. However, it is the after forming thickness that will control the media strength, not the before forming values. Some engineers have either specified too low of an after forming sheet thickness or have not enforced the specified minimum "after forming" sheet thickness. Since after forming thickness varies, the specification criteria should control the minimum thickness value. The "average" thickness or strength is of little consequence since, like links in a chain, a column of media is only as strong as the weakest module. The minimum after forming thickness of any module, in any layer, of a filter layer should be no less than 15 mils. A minimum practical sheet thickness is necessary simply because of the uncertainties in: plastic creep, forming and the slow deformation of plastic materials over time.

In addition to considering the after-forming thickness, specifying the number of sheets in the module should also be done. A useful field check as to the supply of adequate PVC material can be obtained by specifying and verification of a minimum dry weight (lb) per module. A number of engineers have specified minimum dry module weights ranging from 24 to 28 pounds per module. This measurement can be taken onsite during construction. A useful conversion factor for dry weight is:

**DRY WEIGHT CONVERSION**

**Dry module weight (lb.) = 0.0603 X # sheets X BFT**

**where 1) module is from 2 x 4 ft sheets**
**2) PVC specific grav = 1.45**
**3) BFT, mil (Before Forming Thickness)**

## Material Properties

Specifying the properties of individual PVC sheets used to fabricate the modules is critical to assuring quality control. Since PVC sheets are thermoplastic, their properties are affected by the ingredients used in formulating the sheets. Some of the critical tests for assessing properties of PVC sheets are given in Table 2.

## Testing Load

Perhaps the most significant area of misunderstanding in media specification is in the selection of a design test load for the bearing strength test. Designers often do not select an appropriate minimum module test load. The minimum load should reflect a practical test value that accounts for: concentrated loads, field conditions, fabrication variability, the weight of biomass, the weight of pumped transient water, and timing differences (accounting for a 2-hour test to 20-year life). Minimum test loads suggested are:

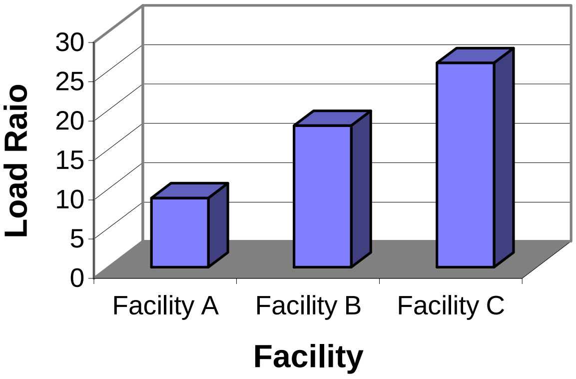
| LAYER | TEST LOAD (psf) |
|---|---|
| Bottom | 1000-1200 |
| Top | 800-1000 |
| All Modules | 500-600 |

A minimum load criteria based on media depth and the actual operating weight of the media should also be stated in the procurement specification. The operating load criteria has historically been based on the estimated live load for VF media, and not with the XF media that is most popular in today's design. In Mabbott's original work with VF media, the load associated with pumped water was considered minor, this may not be true with XF media. Mabbott used an overall factor of 4.0 to equate average live loads measured in the field, to a laboratory short-term test load. This test factor is necessary to account for "creep" of plastic material that will occur over the 20-year life of the media versus the 2-hour test.

Photo 6: Heavy Biogrowth

To explain, Table 3 presents an estimation of test load criteria for a filter with 10 layers of media (20 feet deep). Column B gives the cumulative live load (module plus biomass load) using an average 200 lb (6.25 lb/ft$^3$) per module weight selected for design purposes. The traditional approach to determining the design "minimum" test load (psf) has been to multiply the live load by a test factor. For example, in Column E of Table 3, a test factor of 4 was used to determine the testing criteria of 700 psf for the 7th layer of media using traditional methods. If vertical media was being used, then the true operating weight (including the weight of pumped water) would be only 16% greater than the live load because of the relatively short hydraulic retention time (2 min per 10 ft @ 1.2 gpm/ft$^2$). However with XF media a longer hydraulic retention time of approximately 7 minutes per 10 feet could cause considerably (56 percent) greater operating loads (Column F) then originally planned.

The comparison shown in Table 3 is based on hydraulic retention times for media with fixed nozzle distribution. Rotary distribution with slow rotation may help to reduce the effect of added weight from transient water. However, regardless of the distribution method, design engineers need to take greater care in selecting a test load that accounts for the specific media type, application and weight of pumped water.



A comparison of the estimated operating weight (Plastic Media + Biomass + Pumped Water) for the three facilities described earlier in Table 1 is presented in Figure 1. Figure 1 shows that media at Facility C had three times more load (weight in lbs) to carry than media at Facility A for each pound of plastic supplied. Figure 1 may even be load for XF to VF media (Facility B compared an understatement of the differences in operating to Facility C) since some studies have indicated there can be up to 50 percent more biomass accumulation on XF media then would occur with VF media.

## Specific Test Criteria

Selection of media design criteria should depend upon location of the module in the tower. The bottom layer may be supported by grating or placed directly upon support beams. A beam test may be required to be sure the selected media is capable of supporting the module weight plus the weight of all of the layers of media above, the biota growth, and the water resting on its surface. This combined load must be carried at the maximum temperature for the planned life of the tower.

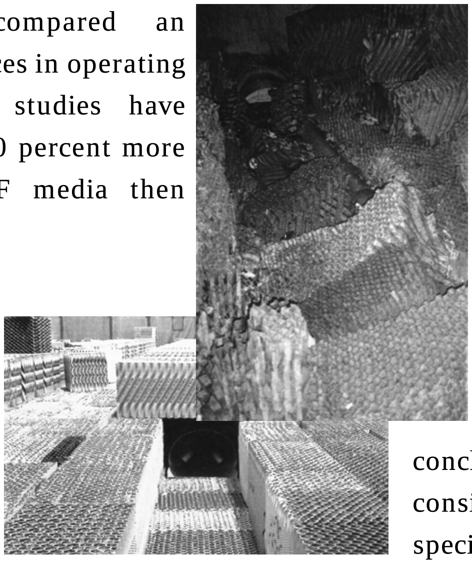


Photo 7: Media Before / After Collapse

Each intermediate layer must be load tested in contact with another module to be sure that it is capable of carrying the module weight plus all media above it plus biota plus water. The top layer has the least weight to support but must resist ultra violet light exposure, hydraulic erosion and foot traffic. The top layer is often a special composition designed for this service which is quite different from other layers.

## Additional Criteria and Cost

A good engineering specification for plastic media should contain other criteria too numerous to mention in this paper. There are several sources for determining suitable criteria, including model specifications and recommendations from media suppliers. Albertson has prepared a draft generic specification for plastic media that should be evaluated. It is suggested that references given at the conclusion of this paper be considered before finalizing media specification.

The question could be asked, if a restrictive engineering specification is used for procurement of plastic media, will this necessarily drive the cost of plastic modules to excessively high levels? Although the price of plastic materials will vary there may only be a 10 to 20 percent increase in cost to assure modules of adequate strength. This is a minor cost when compared to the trauma and expense associated with a media collapse.

Table 4 provides a comparison of the price quotes from 1974 for VF media to a recent price quotation on XF media every bit as beefy as media supplied in the 1970's. As indicated by the price per cubic foot, media supplied in the late 1990's with XF configuration and short-term testing may be as inexpensive as 20 years ago. These bargain prices may be due to improved forming methods, the availability and price of suitable PVC, and other items that do not effect media quality. To assure adequate strength, two media manufacturers (Brentwood Industries and Marley) have stated it is their practice to supply modules with stringent deflection criteria and with adequate test loads. With these standards and a good engineering specification the owner of a trickling filter can be assured of durable, long lasting plastic media.

## CONCLUSIONS

The following conclusions can be made based on our present understanding of media strength.

1) The short-term test is an acceptable method of evaluating media strength with proper specification criteria and verification of short-term to long-term test results.
2) Suggested minimum bearing criteria for standard (27 to 30 $ft^2/ft^3$) media should include:
   a) Detailed bearing strength test.
      - maximum deflection
      - test loads based on operating weight and media depth
      - minimum test loads regardless of depth
      - specific test criteria and test submittals
      - temperature consideration for the worst condition
   b) Minimum sheet thickness both before and after forming.
   c) Minimum weight for dry modules without biomass.
   d) Detailed listing of fabricated module properties including the number of sheets and methods for forming.
   e) Listing of suitable properties for PVC materials used in forming modules.
3) Care needs to be taken in selecting the media type and specification criteria to avoid media collapse.

## REFERENCES

1. Albertson, Orris E., (1997) "Draft, Model Trickling Filter Media Specification" Unpublished, Enviro Enterprises, Inc., Salt Lake City, UT.

2. Mabbott, Jean W., (1982) "Structural Engineering of Plastic Media for Wastewater Treatment by Fixed Film Reactors," First International Conference on Fixed Film Biological processes, Kings Island, OH.